Nov. 9, 1965 AKIRA NAKADA 3,217,081

SOUND VOLUME CONTROLLER FOR ELECTRONIC MUSICAL INSTRUMENTS

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Fig. 1

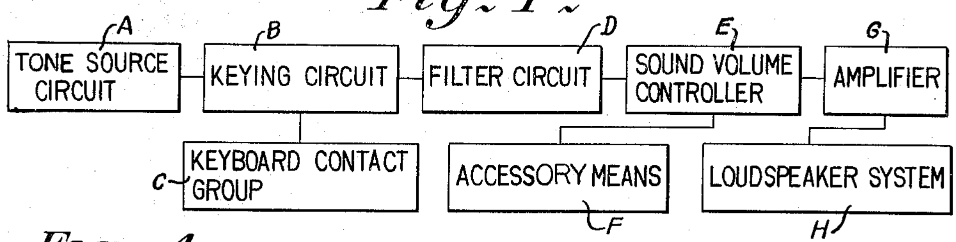
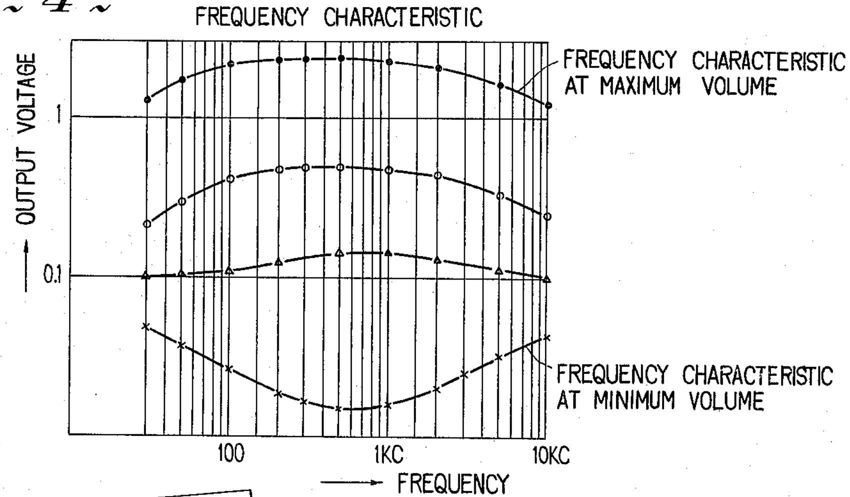


Fig. 4



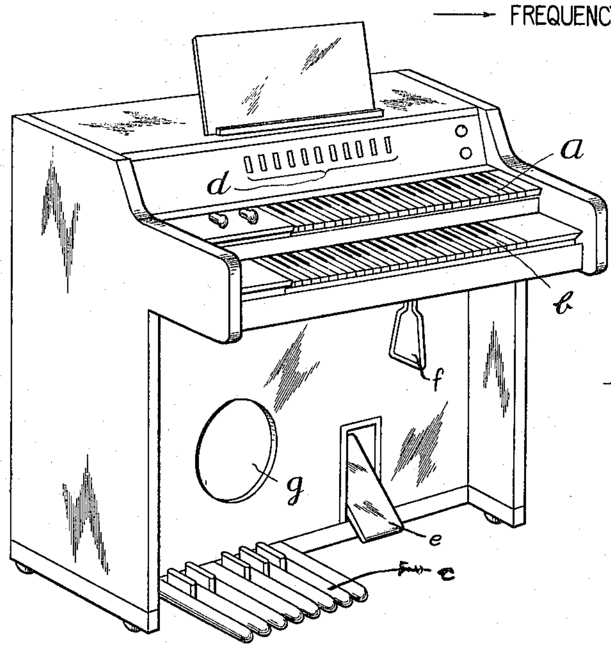


Fig. 2

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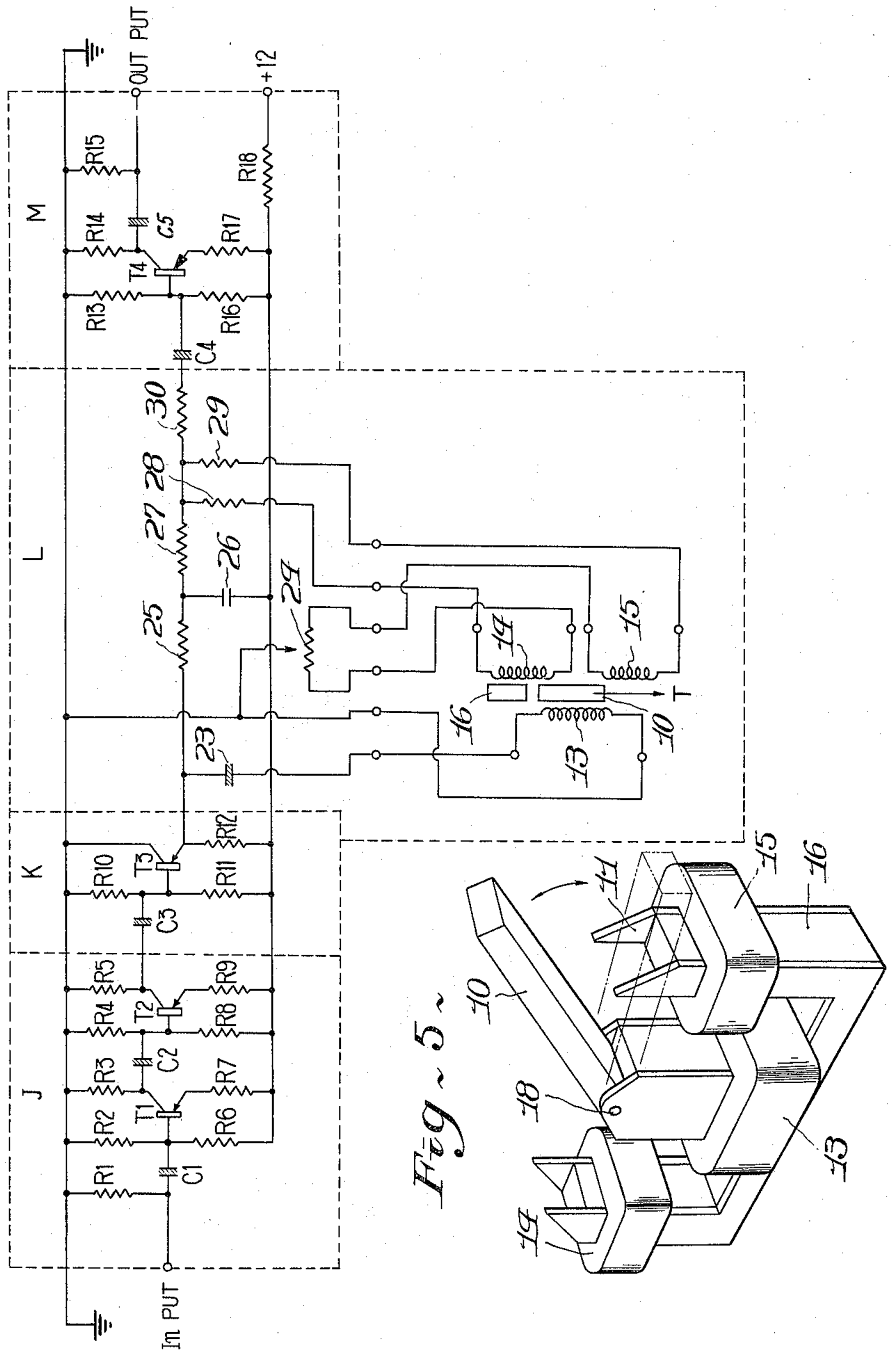

Fig. 3

Fig. 5

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Fig. 6.

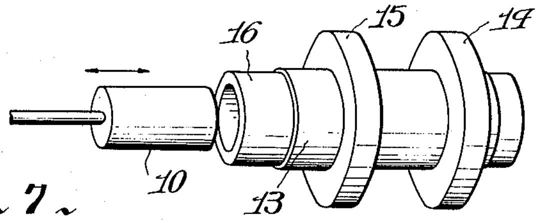


Fig. 7.

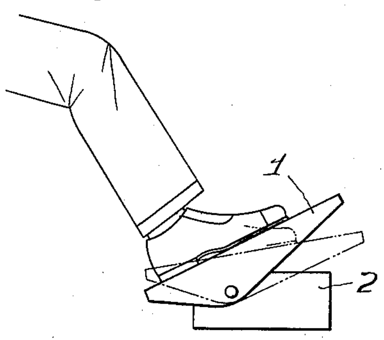


Fig. 9(a).

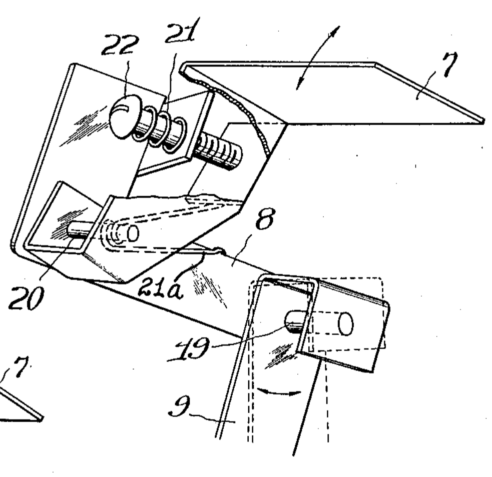
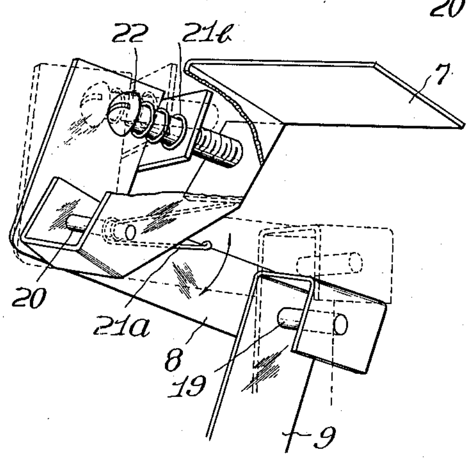


Fig. 9(b).



SOUND VOLUME CONTROLLER FOR ELECTRONIC MUSICAL INSTRUMENTS

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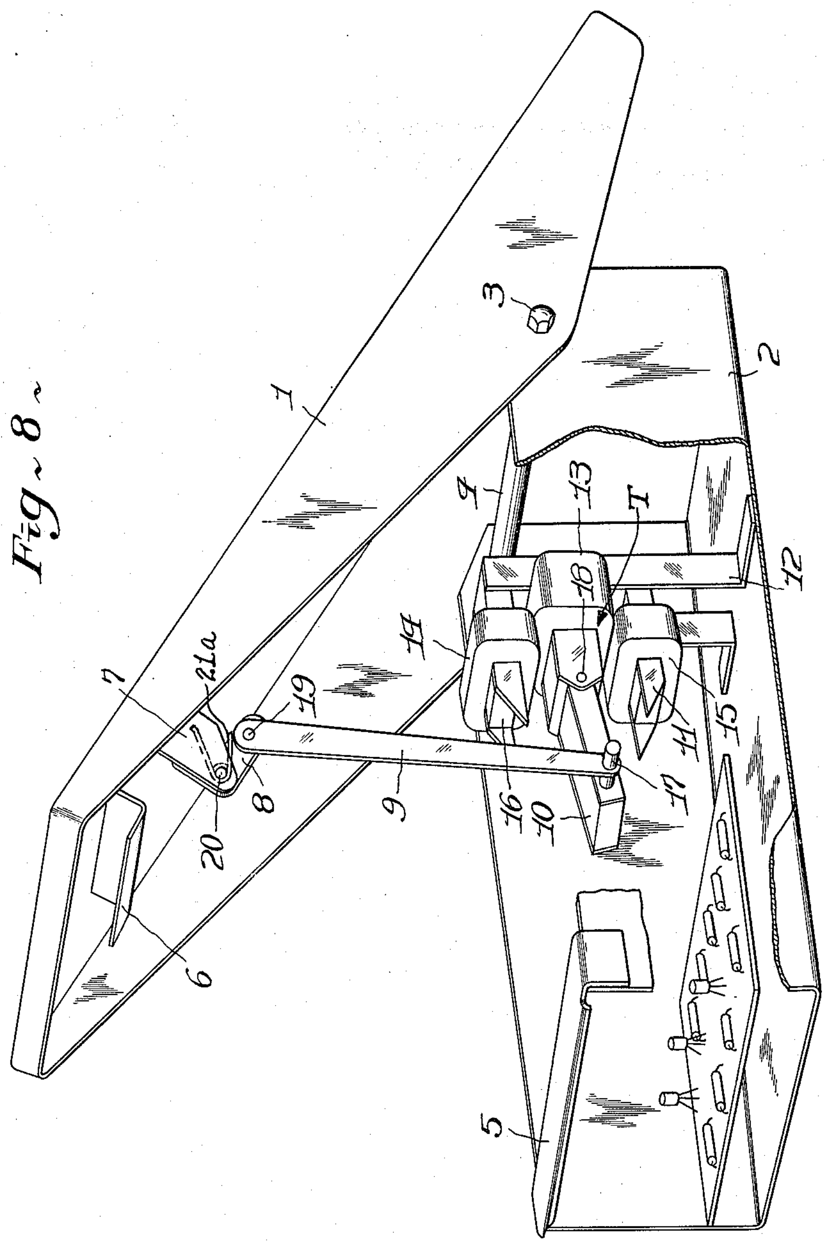

Fig. 8

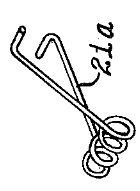

Fig. 9(C)

United States Patent Office

3,217,081

Patented Nov. 9, 1965

3,217,081

SOUND VOLUME CONTROLLER FOR ELECTRONIC MUSICAL INSTRUMENTS

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Filed Feb. 8, 1962, Ser. No. 171,879

5 Claims. (Cl. 84—1.27)

This invention relates to means for controlling the volume, or intensity, of sound of electronic musical instruments, and more particularly it relates to a new apparatus for controlling the sound volume of electronic musical instruments which apparatus utilizes inductance variation as a variable element.

For a full and appreciative understanding of the nature and spirit of the present invention, the following points are presented for review. Music is a means of expressing human emotions by sound, and the methods of employing such means may be divided into two kinds, i.e., those using natural sounds and those using implements. Musical expression is greatly influenced by such elements as that relating to tempo, that relating to the degree of intensity of sound, and that relating to loudness.

Electronic musical instruments, of course, belong to the kind of means of expression wherein implements are used and are required to be such as to render various expressions by simple operations and simple skills. What is considered to be an extremely important element therein is the means of controlling sound volume. An object of this invention is to provide a new and novel sound volume controller for electronic musical instruments, which is simple in construction and precise and easy in its volume controlling operation.

The nature and details of the present invention will be clearly apparent by reference to the following description when taken in conjunction with the accompanying illustrations in which like parts are designated by like reference numerals or letters, and in which;

FIG. 1 is a block diagram indicating the arrangement of a representative electronic musical instrument to which the volume control means of the present invention is applied;

FIGURE 2 is a perspective view indicating a typical electronic musical instrument;

FIG. 3 is a schematic circuit diagram showing an electrical circuit suitable for the volume controller *f* shown in FIG. 2;

FIG. 4 is a graphical representation indicating the frequency characteristic of a volume controller according to the invention;

FIG. 5 is a perspective view indicating one embodiment of the present invention, utilizing a differential transformer which varies inductance;

FIG. 6 is a perspective view indicating another method of utilizing a differential transformer which varies inductance and representing an example of the case wherein a hollow core and a movable core adapted to slide in and slide out of said hollow core are used;

FIG. 7 is a side elevational view, in diagrammatic form, showing one example of a foot-operated application of a volume controller of the invention to an electronic musical instrument;

FIG. 8 is a perspective view, with parts cut away, showing the construction of a volume controller according to the invention;

FIG. 9*a* is a perspective view, with parts cut away, indicating a linkage for driving the moving core member of a transformer suitable for the embodiment of FIG. 8, in normal operation;

FIG. 9*b* is a perspective view of the linkage of FIG. 9*a*; and

FIGURE 9*c* is a perspective view of spring **21*a***.

A representative electronic musical instrument, as indicated in block form in FIG. 1, comprises essentially a tone source circuit A, a keying circuit B, a keyboard contact group C, a filter circuit D, a sound volume controller E, an accessory means F for accomplishing sound volume control, an amplifier G, and a loudspeaker system H.

The above essential parts are incorporated in such an electronic musical instrument as is representatively illustrated in FIG. 2. The controls of this instrument are: a swell keyboard *a*, a great keyboard *b*, a pedal keyboard *c*, stop levers *d* for tone control, a sustain lever *e*, and a sound volume controller *f*. The output music is emitted from a loundspeaker *g*.

The electrical circuit essential for the volume controller E of FIG. 1 comprises, as is shown in FIG. 3, a preamplifier section J, an impedance transducer section K for transducing the impedance of the signal power source, a volume control and low-pass filter section L, and a second preamplifier section M. In FIG. 3, the characters R_1, R_2, . . . R_{18}, **25**, **27**, **28**, **29**, and **30** and C_1, C_2, . . . C_5, C_6, **23**, **26** are, respectively, resistors and condensers, and T_1, T_2, T_3, T_4 are transistors.

In one embodiment of this invention, the volume control and low-pass filter section L includes a tranformer which is composed of a primary coil **13**, secondary coils **14** and **15**, a ferromagnetic stationary core **16**, and a moving magnetic material member **10**. This transformer in practical construction has such adaptations as are illustrated in FIGS. 5, 6, and 8, as will be more fully described hereinafter.

The operation of the above-mentioned parts of an electronic musical instrument will now be described. The output electric oscillation of the electronic musical instrument is formed by the selection of tones by means of the key selection means B and C from the tone source A of the block diagram in FIG. 1 and the passage of these tones through the tone filter D. This output electric oscillation thus formed enters the first preamplifier J shown in FIG. 3 where it is amplified to a certain degree. In the case of this amplifier, the outer impedance is high, and the passing of this output, as it is, directly to a variable element is unsuitable for reasons of characteristics. Therefore, an impedance transducer section K becomes necessary. The signal electric oscillations passes through a capacitor **23** for suppressing direct current and flows through the primary coil **13** of a differential transformer T. The said capacitor **23** has a low impedance with respect to alternating current.

The primary coil **13** and secondary coils **14** and **15** of the differential transformer T are disposed about a ferromagnetic stationary core **16** as shown in FIG. 5. When the electric oscillation current which has passed through the impedance transducer section K of FIG. 3 is caused to flow through the coil **13**, magnetic flux conforming to the electric oscillation is created in the magnetic core **16**. If the resistance and the inductance of the two secondary coils **14** and **15** were identical, the potentials induced in both of the secondary coils **14** and **15** would also be equal in amplitude and phase. When the potentials induced in the two secondary coils **14** and **15** are combined in resistor **30** after passing through the identical resistors **28** and **29**, the algebraic sum of the two potentials is obtained and is applied to the amplifier shown in the block M. If, however, the characteristics of one or the other of the two secondary coils **14** and **15** are modified so that the potentials induced in them are no longer identical but vary in amplitude and phase, then the algebraic sum of these potentials as applied to the input of the amplifier M may also be modified. It is feasible that the input potential to the amplifier M can be reduced to zero, if the potentials induced in the two secondary coils **14** and **15** are of equal amplitudes but opposite in phase. Thus, variation of the input signal to the amplifier M can range between zero and double the potential induced in either of the coils **14** and **15**

One means for achieving a variation in the potentials induced in the coils **14** and **15** is by the construction shown in FIG. 5. The transformer shown in FIG. 5 comprises an E-shaped magnetic core **16** which supports the secondary coils **14** and **15** individually on each of its two outer legs and the primary winding **13** in its center leg. In addition, an I-member **10** of magnetic material is pivoted at one end on the end of the center leg of the core **16**. The I-member **10** can be used to modify the magnetic paths between the primary winding **13** and the two secondary coils **14** and **15**. When the I-member **10** is parallel to the center leg of the core **16**, the two magnetic paths of the core **16** are the same, and the two secondary coils **14** and **15** will have identical potentials induced in them. When, however, the I-member **10** is moved from its central position parallel to the center leg of the core **16** toward either of the coils **14** and **15**, then the reluctance of the magnetic path of one of the coils **14** or **15** will increase and that of the other will decrease. When the member **10** is moved into the position shown in FIG. 5 in heavy lines, then the reluctance of the magnetic path between the primary winding **13** and the secondary coil **15** decreases below the path between the winding **13** and the coil **14**. When the member **10** is in the position shown in faint lines in FIG. 5, then the reluctance of the magnetic path through the coil **15** is at a minimum and that of the path through the coil **14** is at a maximum. Thus, the relative coupling between the primary winding **13** and the two secondary coils **14** and **15** may be varied by changing the position of the member **10**.

The sensitivity of the human ear varies greatly with frequency. That is, if the intensity of sound is reduced the tone of an electronic musical instrument will be heard as if it were also changed. In order to prevent this effect, it is necessary that the frequency characteristic at the time of balance (time of minimum sound volume) be such that the low-frequency tones and high-frequency tones must be raised as indicated in FIG. 4. That is, it is necessary to carry out loudness control.

In the circuit of FIG. 3, the resistors **25** and **27** and the capacitor **26** constitute a low-pass filter, which governs the characteristic of the low-pass band of FIG. 4. The output from the impedance transducer K is taken across the resistance R_{12}. The capacitor **26** is connected through the resistor **25** in parallel with resistor R_{12}. Capacitor **26** varies in impedance with the frequency of the signal applied to it. Thus, it represents a lower impedance to a high frequency signal than it does to a low frequency signal. Therefore, as the frequency of the signal across R_{12} rises, the effective parallel impedance of the R_{12-26} combination falls, and the effective potential of the higher frequency signals also falls. Since the impedance of the resistors **25** and **27** does not change with the frequency of the signals passing through them, the low pass filter **25**, **27** and **26** passes the lower frequency signals very little changed and tends to "short-circuit" the higher frequency signals. The characteristic curves for high-frequency tones are governed by the ratio of the winding turns of the primary coil **13** and the secondary coils **14** and **15**, as been confirmed experimentally. That is, it has been found that, in the high-frequency part, the above relation is due to the capacity caused by leakage between the windings.

When the relative impedances of the two secondary coils **14** and **15** are not quite the same due to manufacturing differences and differences in materials with the I-member **10** in its neutral position, a balance may be achieved between the two by adjusting the potentiometer **24**. This tends to balance the division of the currents flowing in the two coils **14** and **15** by adjusting the total impedances in their series circuits. The currents flowing through the two coils **14** and **15** are combined across the resistor **30** through the identical resistors **28** and **29**. The load on the transformer T is purely resistive, and includes the resistors **28**, **29**, and **30** as well as R_{13}. The load, therefore, does not change with frequency. However, as the position of the I-member **10** is varied, the mutual inductance, or coupling, between each of the two secondary coils **14** and **15** with the primary winding **13** is also varied. The closer the coupling, the more effective the load is upon the circuit. Therefore, as the I-member **10** is positioned close to the coil **15**, the less effect frequency has upon the coil **15** and the more it has upon the coil **14**. However, as the member **10** is moved closer to coil **15**, the inductance of the coil **14** increases, and the lower the induced potential in it becomes. This modifies the signal potential applied by the transformer T to the amplifier M. The filter tends to pass the lower frequency signals more strongly through the T-pad and the higher frequency signals more strongly through the transformed T. This occurs because the inductance of the coil **14** with the movements of the member **10**, tends to decrease the amplitude of the high frequency signals. Thus, the lower frequency signals are combined algebraically across the resistors **30** and **24**, tending to cancel each other to some extent.

A variable resistor **24** is provided for the purpose of correcting any unbalance caused at time of winding. The state of balance can be determined by means of this resistor. Resistors **28** and **29** are provided for improvement of the frequency characteristics, and a resistor **30** is connected in series with the input impedance of the preamplifier M and functions as the load of the volume controller.

The afore-described modification of the balance between the induced voltages of the secondary coils **14** and **15** may be attained by the electro-mechanical mechanism as is shown in FIG. 5, wherein a moving core member **10** is rotatably supported on a pivotal shaft **18**. A wedge-shaped core piece **11** made of a magnetic substance is provided at the end of each leg of the ferromagnetic stationary core **16** so that, when the moving core member **10** approaches the ferromagnetic core **16**, a sudden increase in the sound volume is prevented, and the afore-said balance is gradually changed.

On the basis of the foregoing principles, the volume controller may be reduced to a practical form of such a construction as is illustrated in FIG. 8. The embodiment shown in FIG. 8 comprises a volume controller body frame **2**; a pedal plate **1** supported rotatably on a pivot shaft **4** supported in turn by the frame **2** and provided at its ends with retaining nuts **3**; a differential transformer T which consists of a primary coil **13**, secondary coils **14** and **15**, a ferro-magnetic stationary core **16** of E type, and a moving core member **10**, which is supported within the frame **2** by bracket **12**; a linkage for transmitting movements of the pedal plate **1** to the afore-said moving core member **10**, consisting of a bracket **7** fixed to the pedal plate **1**, an L-shaped link **8** for a safety device, the link **8** and the bracket **7** being pivoted on a pin **20**, and a driving link **9** pivoted to the link **8** by a pin **19** and to the afore-said moving core member **10** by a pin **17**; and means such as members **5** and **6** for stopping the movement of the pedal plate **1** at the end of its operational stroke.

The pedal plate **1** is operated by a foot as indicated in FIG. 7 and can be depressed freely through an angle range of 10 to 45 degrees from horizontal until stopped by the afore-said means **5** and **6**. By varying the angle of depression of this pedal plate **1**, the sound volume is controlled during the playing of the musical instrument. The stop means **5** and **6** prevents the pedal plate

1 from rotating through an angle greater than that necessary for volume control and is provided with material which will absorb surplus energy so as to prevent the emission of contact noise.

The mechanical system of the volume controller shown in FIG. 8 is provided with a safety device and a device for adjusting maximum value as illustrated in the enlarged perspective views of FIG. 9*a* and 9*b*. When the mechanical system is operating in a normal manner, the driving link **9**, undergoes a movement indicated by the dotted lines with the pin **19** as a center of rotation, as shown in FIG. 9*a*. If, however, an operational failure due to some cause occurs in the vicinity of the moving core member **10**, and the system thereby is unable to move correctly, the safety device functions and rotates about the pin **20** as a center as indicated by the dotted lines in FIG. 9*b*, whereby a screw **22** separates away from the bracket **7**. This is, although the moving core member **10** does not move, the force applied to the pedal plate **1** is absorbed by a spring **21***a* to prevent damake to the links **9** and **8** and pins **19** and **17**.

Furthermore, a slight clearance between the moving core member **10** at the end of its full stroke at the time of maximum sound volume and the stationary core **16** is necessary in order to prevent collision between the two parts and emission of mechanical noise. This clearance is created and adjusted by the screw **22**. When this screw **22** is turned, the link **8**, rotating about the pin **20** as a center, varies its angular orientation relative to the bracket **7**, and the position of the pin **19** is shifted. As a result, the relative position of the pin **17** also changes. Thus, fine adjustment is possible. A spring **21***b* is provided about the screw **22** to prevent loosening of the screw **22**.

In the volume controller of the present invention, the differential inductance means need not be limited to a transformer such as that shown in FIG. 5 with ferromagnetic core, but may be a tube-type core transformer such as that indicated in FIG. 6.

The transformer T of FIG. 5 can be modified so far as the inductance thereof can be continuously varied. For example, such a modified transformer is shown in FIG. 6, wherein a primary coil **13** is wound around a hollow ferromagnetic core **16** and secondary coils **14** and **15** are wound around said primary coil in spaced relation, and a movable core member **10** is disposed so as to slide in and slide out of said core **16**. In this transformer, inductance of the circuit can be continuously varied in accordance with the position of the movable core relative to that of the stationary core **16**.

Although this invention has been described with respect to a particular embodiment thereof, it is not to be so limited as changes and modifications may be made therein which are within the full intended scope of the invention, as defined by the appended claims.

What is claimed is:

1. In an electronic musical instrument having a frequency-amplitude characteristic which droops at the high and at the low frequencies at the higher amplitudes and which includes a tone source, means for compensating for said frequency-amplitude drooping characteristic, said compensating means comprising an amplifier for the output from said tone source, a variable filter circuit, means for connecting the output of said amplifier to the input of said filter circuit and for matching the output impedance of the amplifier with the input impedance of the filter circuit, said filter circuit comprising a resistance-capacitance T-pad low-pass circuit which tends to compensate for the drooping frequency-amplitude characteristic of said instrument at the low frequencies and a variable inductance device, said variable inductance device modifying the amplitude characteristics of said instrument, means for applying the signal output from said amplifier simultaneously to said low-pass circuit and to said inductance device, means for combining the output from the low-pass circuit and the output from said inductance device to provide an overall compensating characteristic which varies with amplitude, said inductance device comprising a pair of coils having a common input and being connected in parallel at one end and differentially at the other end, the output from said coils being taken from the paralleled end, and means for increasing the inductance of one of said coils with respect to the other of said coils so as to modify the signal output of said coils to be combined with the signal output from said low-pass circuit.

2. The instrument defined in claim **1** in which said inductance device comprises a transformer having a single primary winding as the common input and a pair of substantially identical secondary coils, a magnetic core passing through said primary winding and said pair of secondary coils, and means for differentially modifying the reluctance of the magnetic path coupling each of said secondary coils with said primary winding.

3. The instrument defined in claim **2** wherein said magnetic core comprises a generally E-shaped core having a secondary coil on each of its outer legs and the primary winding on the center leg, and further comprising an I-member pivoted on the end of the center leg and adjustable to decrease the air gap between the center leg and one of the outer legs.

4. The instrument defined in claim **3** wherein said inductance device is mounted in a housing, at least one portion of said housing being movable with respect to the rest of the housing, and means for connecting said I-member to said movable portion.

5. The instrument defined in claim **2** wherein said transformer comprises a hollow magnetic core having said secondary coils spaced apart thereon, and a magnetic slug movable through said hollow core to modify the coupling between said primary and one of said secondary coils.

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