United States Patent [19]

Ohno

[11] **3,708,605**

[45] **Jan. 2, 1973**

[54] **MAGNETICALLY OPERATED KEYING DEVICE FOR AN ELECTRONIC MUSICAL INSTRUMENT WITH TOUCH RESPONSIVE CONTROL**

[75] Inventor: **Junji Ohno,** Hamamatsu, Japan

[73] Assignee: **Nippon Gakki Seizo Kabushiki Kaisha,** Hamamatsu-shi, Shizuoka, Japan

[22] Filed: **June 23, 1970**

[21] Appl. No.: **48,959**

[30] **Foreign Application Priority Data**

June 28, 1969	Japan	44/61426
June 28, 1969	Japan	44/61427
June 28, 1969	Japan	44/61428
June 28, 1969	Japan	44/61429
Aug. 19, 1969	Japan	44/78648
Aug. 19, 1969	Japan	44/78649

[52] **U.S. Cl.** **84/1.1,** 84/1.15, 84/1.27, 84/DIG. 7

[51] **Int. Cl.** **G10h 3/08**

[58] **Field of Search** ..... 84/1.01, 1.09, 1.1, 1.15, 1.26, 84/1.27, DIG. 7, 1.13, 1.14

[56] **References Cited**

UNITED STATES PATENTS

R27,015	12/1970	Dijksterhuis et al	84/1.26
2,261,346	11/1941	Demuth	84/1.15 X
2,321,366	6/1943	Demuth	84/1.15
2,799,196	7/1957	Alvarez	84/1.15 X
2,905,039	9/1959	Alvarez	84/1.15 X
3,580,979	5/1971	Amano	84/1.1
3,248,470	4/1966	Markowitz et al	84/1.1
3,313,877	4/1967	Boenning	84/1.01
3,255,293	6/1966	Walker	84/1.15 X
3,353,030	11/1967	Michel	84/1.01 X
3,530,756	9/1970	Chapman	84/1.15

FOREIGN PATENTS OR APPLICATIONS

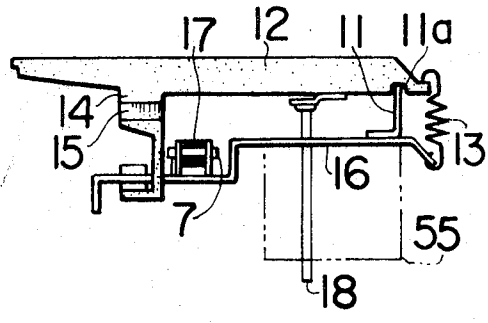
1,164,422	9/1969	Great Britain	84/1.26

Primary Examiner—Laramie E. Askin
Assistant Examiner—Stanley J. Witkowski
Attorney—Cushman, Darby & Cushman

[57] **ABSTRACT**

In electronic musical instruments, by arranging a magnetically-conducting member secured to each key in spaced relationship relative to a fixed common magnetized member so that when the displaceable magnetism-conducting members shift their positions relative to a fixed common magnetized member in accordance with the degree of depression of keys, the variance in the intensity of the magnetic flux generated between said movable and fixed members is markedly reduced as compared with the arrangement where a magnetized member is secured to each. Further the manufacture of the instrument can be performed at a much lower cost and with much greater ease using this arrangement.

12 Claims, 49 Drawing Figures



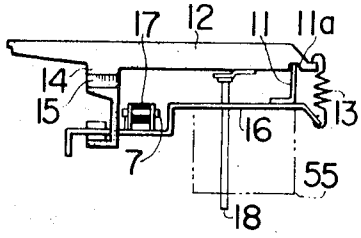


FIG. 1

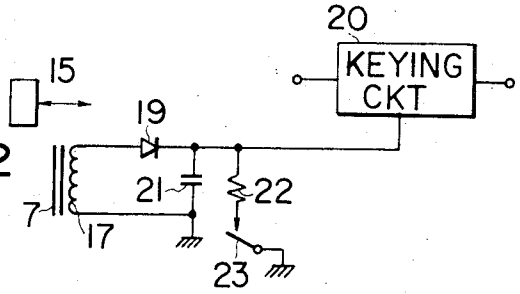
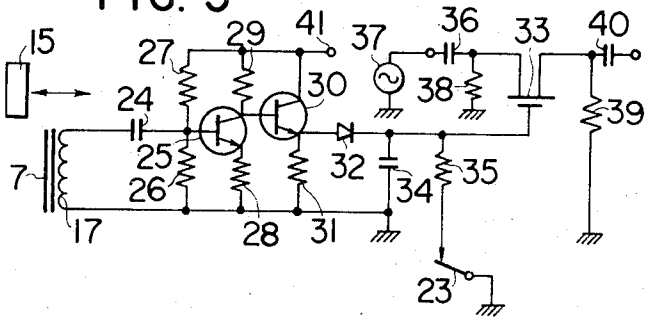


FIG. 2

FIG. 3



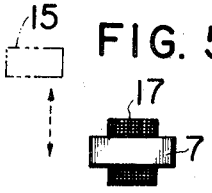


FIG. 5a

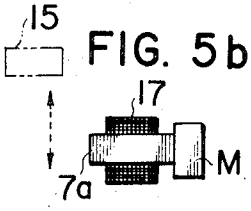
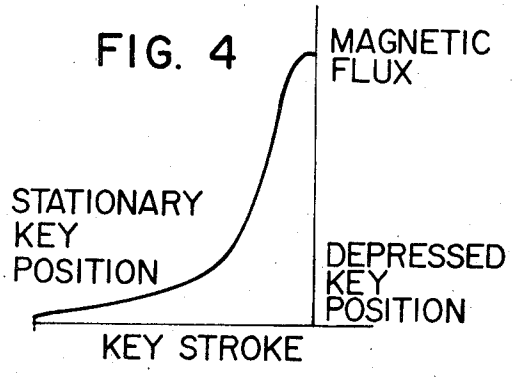


FIG. 5b

FIG. 4



INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

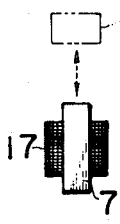


FIG. 6a



FIG. 6b

FIG. 8

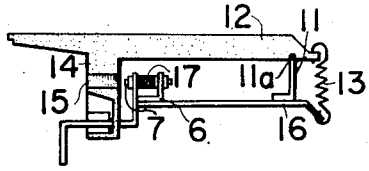


FIG. 10

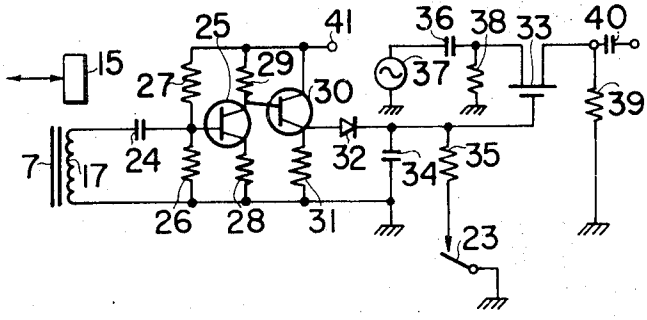


FIG. 9

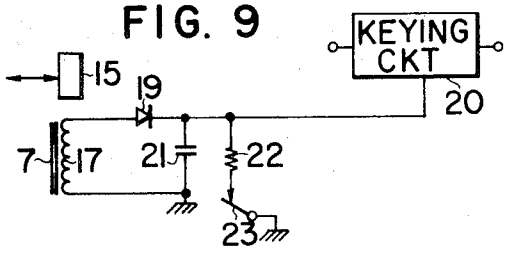


FIG. 7a

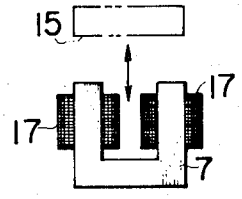
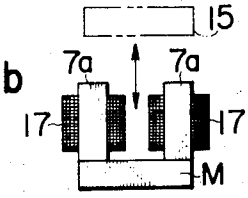


FIG. 7b



INVENTOR.
JUNJI OHNO

BY CUSHMAN, DARBY & CUSHMAN

ATTORNEYS

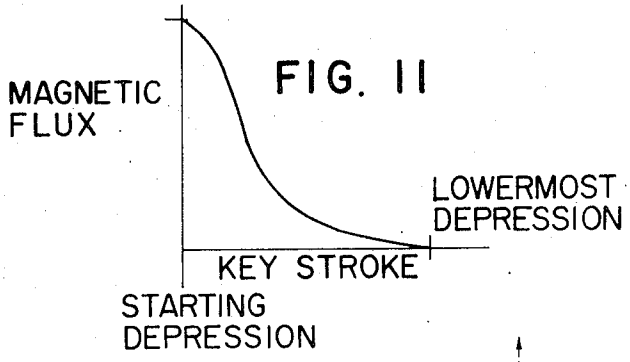


FIG. 11

FIG. 12a

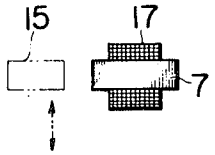
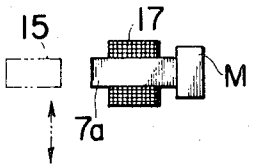


FIG. 12b



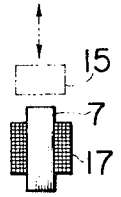


FIG. 13a

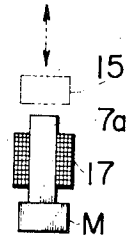


FIG. 13b

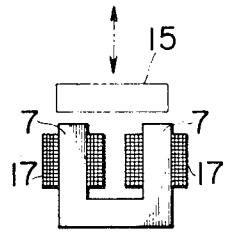


FIG. 14a

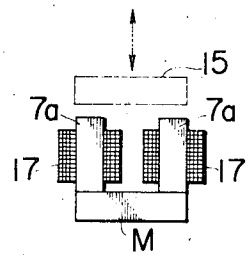


FIG. 14b

INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

FIG. 16

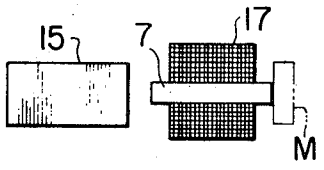


FIG. 17

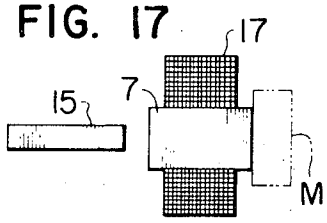


FIG. 18

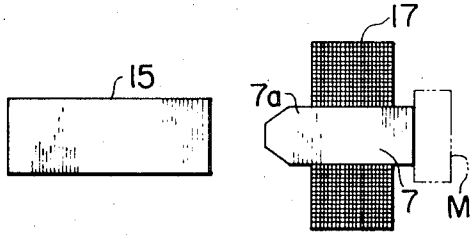


FIG. 15

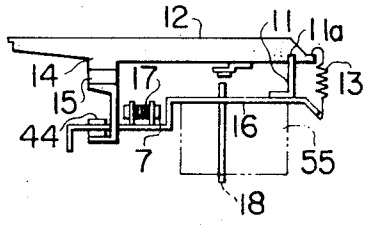


FIG. 19

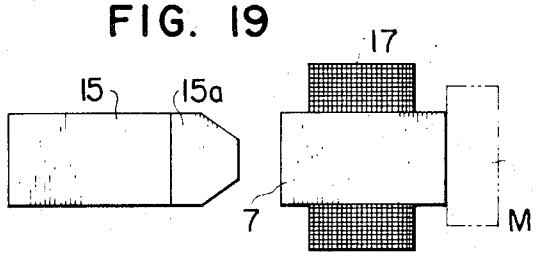


FIG. 20(b)

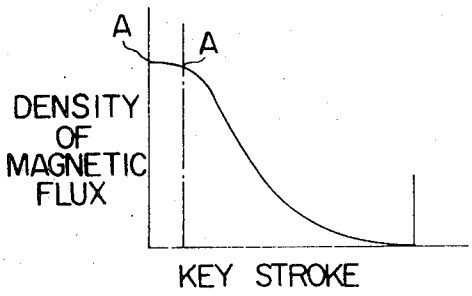
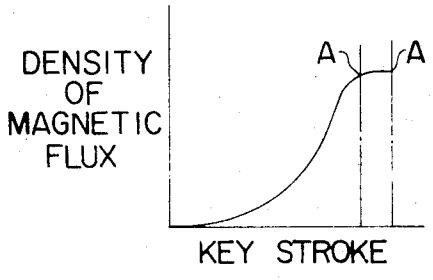


FIG. 20(a)



INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

FIG. 21a

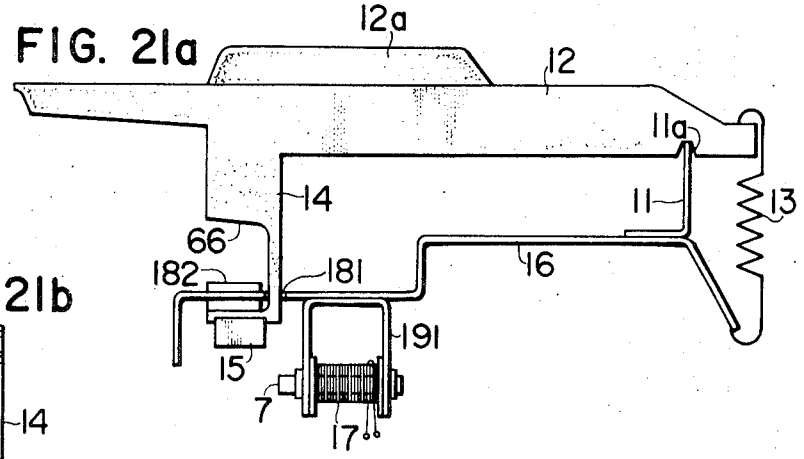


FIG. 21b

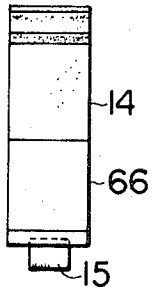


FIG. 22a

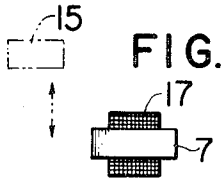


FIG. 22b

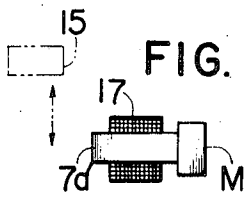


FIG. 23a

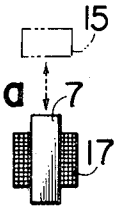


FIG. 23b

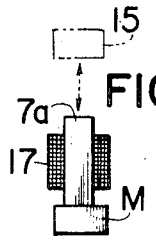


FIG. 24a

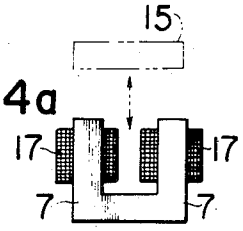
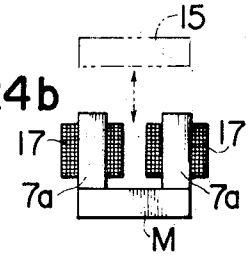


FIG. 24b



INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

FIG. 25

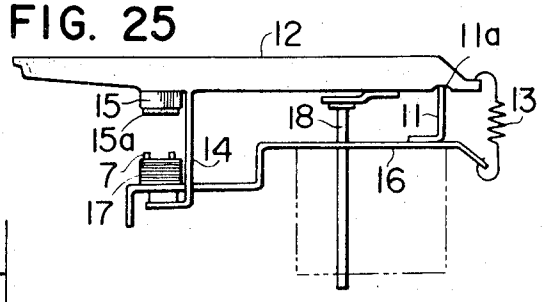


FIG. 26

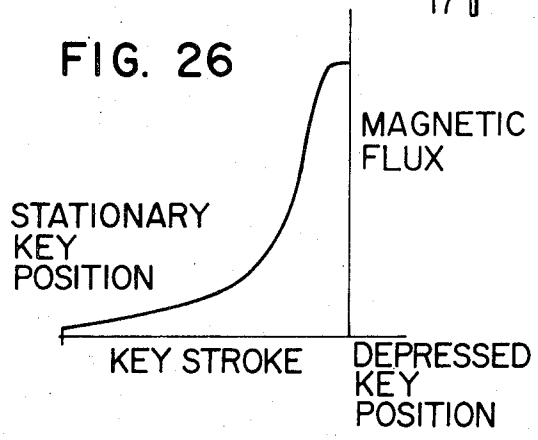


FIG. 27

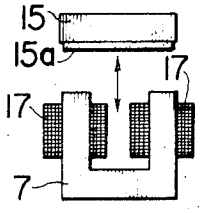
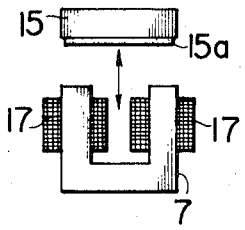


FIG. 29a



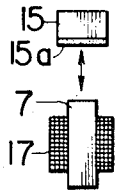
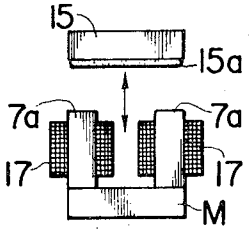


FIG. 28a

FIG. 29b



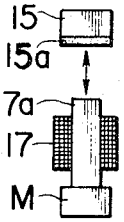


FIG. 28b

INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

FIG. 30

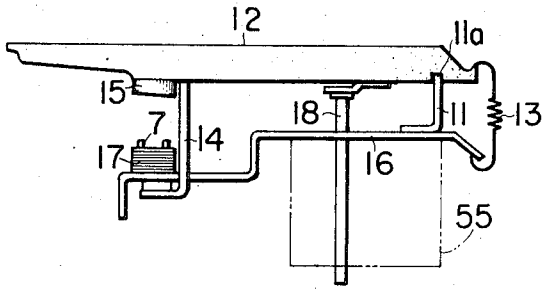


FIG. 31

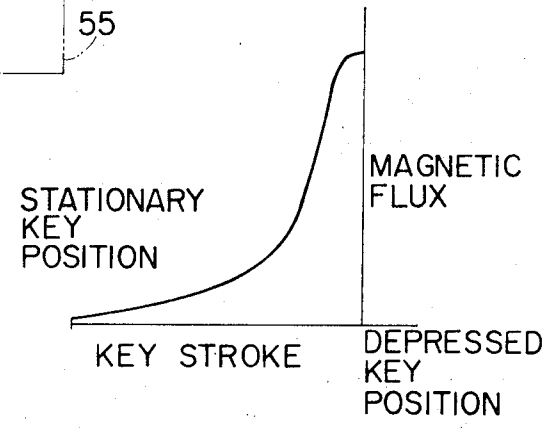


FIG. 32

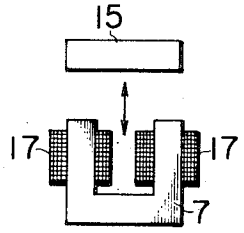


FIG. 33a

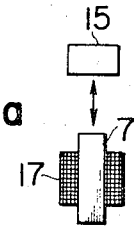


FIG. 33b

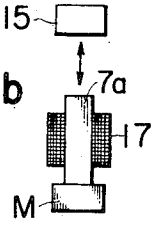


FIG. 34a

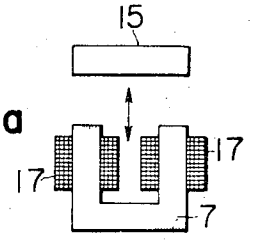
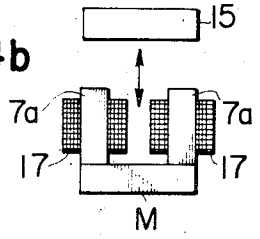


FIG. 34b



INVENTOR.
JUNJI OHNO
BY CUSHMAN, DARBY & CUSHMAN
ATTORNEYS

MAGNETICALLY OPERATED KEYING DEVICE FOR AN ELECTRONIC MUSICAL INSTRUMENT WITH TOUCH RESPONSIVE CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is concerned with an electronic musical instrument, and more particularly, it relates to an improved musical instrument which permits the tone signals, especially the tone signal build-up pattern and the volume (intensity) of sound, to be controlled by the degree of depression of keys.

2. Description of the Prior Art

In known electronic musical instrument, such as an electronic organ, which uses a key board, the keying of tone signals was performed merely by a key switch or switches so that the tone envelope was not satisfactorily controlled. In contrast to this, in a piano, for instance, which is a purcussive musical instrument, the profile as well as the breadth of the tone envelope vary immensely depending on the degree of the pressure applied onto the keys, i.e., depending on whether the keys are depressed strongly and quickly or they are depressed softly, and such difference causes variation in the effect of the sound of the music being played.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to eliminate the aforesaid drawback of the electronic musical instrument of the prior art and to provide an improved electronic musical instrument which permits touch-responsive control so that the tone envelope is variable depending on the degree of the force applied onto the keys in such a way that greater generated energy is produced from greater speed at which the keys are depressed and from greater depth to which the keys are depressed, at which time the displaceable magnetism-conducting members which are normally spaced from the fixed common magnetized member approach progressively toward the latter common member, and to thereby prevent mis-touch on the part of the player.

Another object of the present invention is to provide an improved electronic musical instrument which permits touch-responsive control so that it can produce sounds whose tone envelope is variable with the degree of the force applied onto the keys in such a way that loud trill sounds are produced even from a great speed at which the keys are depressed and from a shallow depth of depression of the keys so as to be suitable for loud trill playing by arranging the displaceable magnetism-conducting members which are normally positioned close to fixed common magnetized member so as to be caused to move away from said normal positions as the keys are struck.

Still another object of the present invention is to provide an improved electronic musical instrument which permits touch-responsive control so that it can absorb the errors in the positions in which the magnetism-conducting members are provided relative to the fixed common magnetized member, by arranging them so that the end face area of either one of these two kinds of members is broader than that of the other member to insure that the density of the magnetic flux generated therebetween will not vary even if there exist some positional errors of these members when the instrument is fabricated.

Yet another object of the present invention is to provide an improved electronic musical instrument which permits touch-responsive control so that, by arranging all of the displaceable magnetism-conducting members of both the white and the black keys so as to be aligned in a row on the key legs located at the remotest positions — commonly for both of these two types of keys — from their pivotal fulcrums, the displaceable magnetism-conducting members can produce the greatest lengths of stroke to greatly facilitate the generation of magnetic flux of varying densities between said displaceable magnetism-conducting members and the fixed common magnetized member, thereby making the trill playing easy and greatly mitigating the problem of dimensional precision of the component members in their designing as well as their manufacture.

A further object of the present invention is to provide an improved electronic musical instrument which permits touch-responsive control so that, by the provision of a resilient member between the displaceable magnetism-conducting members and the fixed common magnetized member, there is produced no mechanical contact noise between said movable member and said fixed member when the keys are struck strongly, and the relative close positions of these two members can be controlled by the degree of depression of the keys so that the regions of weak sound are limited.

Still further object of the present invention is to provide an improved electronic musical instrument of the type described in which, instead of the provision of the resilient member between the displaceable magnetism-conducting members and the fixed magnetized member, either one of these members are made with a magnetized rubber or like resilient materials to provide similar effect, but to curtail the cost of manufacture.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to one embodiment of the present invention;

FIG. **2** is a circuit diagram, showing the keying control circuit employed in the keyboard mechanism shown in FIG. **1**;

FIG. **3** is a circuit diagram, showing another example of the keying control circuit;

FIG. **4** is a magnetic flux distribution chart of the coil incorporated in said keyboard mechanism shown in, for example, FIG. **1**;

FIGS. **5***a*, **5***b*; FIGS. **6***a*, **6***b* and FIGS. **7***a*, **7***b* are schematic diagrams, respectively, showing modified examples of the essential parts of the keyboard mechanism of said one embodiment, respectively;

FIG. **8** is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to another embodiment of the present invention;

FIG. **9** is a circuit diagram, showing the output sound loudness control circuit constituting the electronic musical instrument shown in, for example, FIG. **8**;

FIG. **10** is a circuit diagram, showing another example of the output sound loudness control circuit;

FIG. **11** is a magnetic flux distribution chart of the coil relative to the key stroke in the keyboard mechanism shown in FIG. **8**;

FIGS. 12*a*, 12*b*, FIGS. 13*a*, 13*b* and FIGS. 14*a*, 14*b* are schematic diagrams, respectively showing modified examples of the essential parts of the keyboard mechanism of said another embodiment;

FIG. 15 is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to still another embodiment of the present invention;

FIGS. 16 through 19 are schematic side elevations, showing the dimensional relationship between the displaceable magnetism-conducting member and the fixed common magnetized member;

FIGS. 20*a* and 20*b* are magnetic flux distribution charts of the sound loudness control coil used in said still another embodiment relative to the varying stroke of the key;

FIG. 21*a* is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to yet another embodiment of the present invention;

FIG. 21*b* is a schematic front elevation of the key of the keyboard mechanism shown in FIG. 21*a*;

FIGS. 22*a*, 22*b*, FIGS. 23*a*, 23*b* and FIGS. 24*a* and 24*b* are schematic diagrams, respectively, showing modified examples of the essential parts of the keyboard mechanism of said yet another embodiment of the present invention;

FIG. 25 is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to a further embodiment of the present invention;

FIG. 26 is a magnetic flux distribution chart of the coil incorporated in the keyboard mechanism shown in FIG. 25;

FIG. 27, FIGS. 28*a*, 28*b* and FIGS. 29*a*, 29*b* are schematic diagrams, respectively, showing modified examples of the essential parts of the keyboard mechanism of said a further embodiment of the present invention;

FIG. 30 is a schematic side elevation, showing a keyboard mechanism of an improved electronic musical instrument according to a still further embodiment of the present invention;

FIG. 31 is a magnetic flux distribution chart of the coil incorporated in the keyboard mechanism shown in FIG. 30; and

FIG. 32, FIGS. 33*a*, 33*b* and FIGS. 34*a*, 34*b* are schematic diagrams, respectively, showing modified examples of the essential parts of the keyboard mechanism of said a still further embodiment of the present invention.

It should be understood that like parts are indicated by like reference numerals for the simplicity of explanation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be hereunder described in further detail with respect to one embodiment of the present invention by referring to the accompanying drawings.

In FIG. 1, there is shown schematically a keyboard mechanism of an improved electronic musical instrument. A key 12 is pivotably supported at one end by a fulcrum 11*a* provided by a supporting rod 11. A spring means 13 is provided at the rear end of said key 12 in such a way that said key 12 is normally held in, for example, its horizontal position. A leg 14 extends downwardly from the lower surface of said key 12 near the foremost end on the side opposite to the location of said fulcrum 11*a*. A magnetism-conducting member 15 such as a soft iron piece is attached to the lowermost end face of said leg 14. A frame 16 is arranged below said key 12 at a predetermined distance therefrom. Said supporting rod 11 which provides said fulcrum 11*a* by its top end edge for the key 12 is coupled, at the other end, to said frame 16. A coil 17 is secured to the upper surface of said frame 16 at a site close to the location of said leg 14. This coil 17 contains therein a magnetic core or a core 7 magnetized by some other magnet. This assembly of the coil 17 and the core 7 is arranged so that the relative positions of the opposing end faces of the magnetism-conducting member 15 and the core 7 will progressively become closer to each other as said key 12 is depressed and as the leg 14, accordingly, is lowered in its position. An actuator 18 of a key switch 55 is provided below said key 12, and passes downwardly through said frame 16. This actuator is capable of shifting its position as said key 12 is depressed.

Said coil 17 constitutes a keying control circuit. As shown in FIG. 2, one end of the coil 17 is grounded, and the other end is connected, via a rectifier 19 such as a diode, to a keying circuit 20. The input terminal of this keying circuit 20 is grounded via a capacitor 21 and also via a resistor 22 and a normally closed contact strip 23 of the key switch 55.

Another example of the keying control circuit is shown in FIG. 3. In this modified example, one end of the coil 17 is grounded and the other end is connected to the base electrode of an n-p-n type transistor 25 via a capacitor 24. This base electrode is grounded via a resistor 26 and further is connected to a D.C. source 41 via a resistor 27. The emitter electrode of said transistor 25 is grounded via a resistor 28, whereas the collector electrode is connected to said D.C. source 41 via a resistor 29, and is further connected to the base electrode of an n-p-n type transistor 30. The collector electrode of this transistor 30 is directly connected to the D.C. source 41, whereas the emitter electrode is grounded via a resistor 31 and further is connected to the gate electrode of a field effect transistor (FET) 33 via a rectifier 32 such as a diode. The gate electrode of this FET 33 is grounded via a capacitor 34 and also via a resistor 35 and a normally closed contact strip 23 of the key switch 55. The source electrode of said FET 33 is grounded via a resistor 38 and is further connected to a tone generator circuit 37 via a capacitor 36, whereas the drain electrode is grounded via a resistor 39 and further is connected to a second stage device such as an amplifier via a capacitor 40.

In an electronic musical instrument having the aforesaid arrangement, it should be understood that, in the normal unactuated state of the key 12, there is caused no change in the magnetic flux in said coil 17, and also the normally closed contact 23 remains to be closed. Under such a state of the instrument, the key 12 may be depressed. Whereupon, the displaceable magnetism-conducting member 15 is lowered in its position in such a way that it progressively approaches toward the coil 17 at a speed with which the key 12 is

depressed, and that it will face said coil **17** at certain desired relative positions. During the course of the approach of this displaceable magnetism-conducting member **15** toward the coil at a certain speed, there arise progressive changes in the magnetic flux in both the magnetized core **7** and the coil **17**, generating an electromotive force therein. In the control circuit shown in FIG. **2**, this electromotive force is rectified by the rectifier **19** and is smoothed by the capacitor **21** and is led to the keying circuit **20**, in which the tone signal coming from a tone generator circuit (not shown) is controlled. More specifically, when the key **12** is depressed or struck strongly, the displaceable magnetism-conducting member **15** will be caused to approach the coil **17** at a great speed and will be positioned to face the latter. Accordingly, an intensive electromotive force is generated in the coil **17**. As a consequence, the tone signal supplied from the tone generator circuit is delivered, as an intensive force, to the next stage device. On the contrary, when the key **12** is depressed softly, the displaceable magnetism-conducting member **15** will approach the coil **17** at a small speed and will travel for only a substantially limited distance toward the coil **17**. Accordingly, the electromotive force generated is small in degree. For this reason, the tone signal coming from the tone generator circuit is delivered, with a small amplitude, to the subsequent stage.

Description will hereunder be directed to the control circuit shown in FIG. **3**. The electromotive force generated in the coil **17** is amplified by the transistor **25** and this amplified electromotive force is derived at the emitter follower of the transistor **30** to be impressed onto the gate electrode of the FET **33**. This FET **33** serves to control the conduction of the tone signal delivered from the tone generator circuit **37**. More specifically, when there is generated an intensive electromotive force in the coil **17**, a very high potential is applied to the gate electrode of the FET **33** and a large tone signal is derived at the output of the same. Whereas, when there is generated a small electromotive force in the coil **17**, a relatively low potential is impressed onto the gate electrode, and accordingly, there is derived a small output tone signal. As stated above, when the key **12** is struck or depressed strongly (meaning at a relatively great speed), there is obtained an intensive tone signal, whereas when the key **12** is depressed softly (meaning at a relatively low speed), there is derived a small output tone signal. Thus, there will arise changes in the volume of the output sound depending on the degree of force and speed with which the key **12** is depressed, and in this way, it is possible to obtain a varying performance effect as if from a piano, i.e., a so-called touch-responsive control.

FIG. **4** shows the manner in which the magnetic flux passing through the coil **17** changes. The vertical axis represents magnetic flux, whereas the horizontal axis represents key stroke. As will be understood from this magnetic flux distribution chart, magnetic flux undergoes relatively limited changes during the initial stage of travel of the displaceable magnetism-conducting member **15** from its normal stationary position to its position at which it faces the coil **17** as the key **12** carrying this member **15** is depressed downwardly. However, the magnetic flux through the coil **17** shows relatively intensive changes toward the end of the travel of said member **15**. Since there is generated an electromotive force in the coil **17** in accordance with the degree of changes in the intensity of the magnetic flux, it will be understood that, even when the key **12** is depressed at a uniform speed, there will be generated relatively small electromotive forces at relatively shallow positions of the key which is depressed, resulting in a small output sound derived. In contrast to this, relatively intensive electromotive forces are generated at relatively deep positions of the key which is depressed, causing a relatively increased intensity of the output sound. This nature will be advantageous for the following performances.

Above all, the aforesaid tendency is quite useful and convenient for trill playing. More specifically, trill playing features repetition of shallow depression of keys at very small time intervals between each two depressions. Since this trill playing itself is a very conspicuous and prominent type of performance, it will be better to produce relatively small sounds of trill from the viewpoint of obtaining an intensity balance of sounds relative to the other sounds caused by the depression of other keys during the music being played. Also, even when there occurs some mis-touch (for example, when a finger of the player touches an adjacent key by mistake), there will be produced no audible sound when the improper key is touched very softly, and such a mis-touch will never become noticeable to the audience. Thus, the performance of the instrument will become convenient and easy. Furthermore, when the key returns to its normal position, the key may bounce. However, such a bouncing takes place only in the vicinity of the normally stationary position of the key, and there will hardly appear any sound from the bouncing key.

Since the key **12** is provided with a displaceable magnetism-conducting member **15**, the weight of the key as a whole is increased to an appropriate extent, providing an improved feeling of touch. On the other hand, in the vicinity of the lowermost position of the depressed key, the weight of the key will be relieved to some extent because of the attractive force exerted by the magnetized core **7**, so that the touch at such a position of the key will become close to that of keys of a piano. The manner in which the coil **17** is wound around the magnetized core **7** and the manner in which the displaceable magnetism-conducting member **15** is caused to approach or part away from this coil **17** may be modified as required as shown in FIGS. **5***a*, **6***a* and **7***a*. Also, instead of using a magnet serving as the magnetized core **7**, a piece of non-magnetized core of relatively high magnetic permeability usually referred to as being magnetic material may be used. In such a case, this non-magnetized core **7***a* may be secured to a piece of magnet M — which has been magnetized beforehand in a predetermined polarity — in a manner as shown in FIGS. **5***b*, **6***b* or **7***b*, to magnetize said core **7***a*.

In another embodiment shown in FIG. **8**, a number of keys generally indicated at **12** which are arranged in a row each is pivotably supported by a fulcrum **11***a* of a supporting rod **11** on the lower face of said key near its rear end. As in the preceding embodiment, one end of a spring means **13** is secured to the rear end of the key **12** so that the key normally may be able to restore its ini-

tial position which may be, for example, horizontal. A leg **14** depends downwardly from the lower face of said key **12** in the vicinity of the fore end thereof. A magnetism-conducting member **15** such as a piece of soft iron is interposed intermediate of the length of said projecting leg **14**. On the other hand, a frame **16** is provided below said key **12** in parallel spaced relation therewith. Said supporting rod **11** is securely supported on said frame **11** near its rear end. The other end of said spring **13** is secured to the rear end of said frame **16**. A coil **17** is secured to a supporting frame **6** provided on said frame **16** at a position close to said leg **14**. This coil **17** contains therein a magnetic core or a core **7** which has been magnetized beforehand by some other magnet. This core **7** is arranged so that it is in a position in which it is close to and faces said displaceable magnetism-conducting member **15** whenever the key **12** is in its normal stationary position, and that the core **7** parts away from said member **15** as the key **12** is lowered in its position progressively. Though not shown, there are provided below said key **12** a key switch and an actuating means for driving said key switch.

The coil **17** constitutes an output sound volume control circuit as shown in, for example, FIG. **9**. MOre specifically, one end of the coil **17** is grounded, and the other end is connected to a keying circuit **20** via a rectifier **19** such as a diode. The output terminal of said rectifier **19** is grounded via a capacitor **21** and via a serial circuitry consisting of a resistor **22** and a normally closed contact strip **23** of said key switch (not shown). Tone signals from a tone generator are introduced into said keying circuit **20**.

Another example of said output sound volume control circuit is shown in FIG. **10**. In this example, one end of the coil **17** is grounded, and the other end is connected to the base electrode of an n-p-n type transistor **25** via a capacitor **24**. This base electrode is grounded via a resistor **26** and also is connected to a D.C. source **41** via a resistor **27**. The emitter electrode of this transistor **25** is grounded via a resistor **28**, whereas the collector electrode is connected to said D.C. source **41** via a resistor **29**, and further is connected to the base electrode of an n-p-n type transistor **30**. The collector electrode of this transistor **30** is connected directly to said D.C. source **41**, whereas the emitter electrode is grounded via a resistor **31**, and further is connected to the gate electrode of an FET **33** via a rectifier **32** such as a diode. This gate electrode further is grounded via a capacitor **34** and via a serial circuitry consisting of a resistor **35** and the normally closed contact strip **23** of the key switch. The source electrode of said FET **33** is connected to the tone generator circuit **37** via a capacitor **36** and further is grounded via a resistor **38**, whereas the drain electrode is grounded via a resistor **39** and further is connected to a next stage device such as an amplifier via a capacitor **40**.

In an electronic musical instrument having the aforesaid arrangement, when the key **12** is in its normal stationary position, the key switch is not driven, nor is there generated an electromotive force in the coil **17**. Accordingly, no output is produced. When, subsequently, the key **12** is depressed and accordingly is lowered in its position, the key switch is driven via the actuating means so that the normally close contact strip **23** is opened. At the same time, the displaceable magnetism-conducting member **15** is displaced in its position at a certain speed. Whereupon, there is produced a sequential change in the magnetic flux through the coil **17** which is wound around the core **7**, and as a result, there is generated an electromotive force in the coil **17**. In the control circuit shown in FIG. **9**, this electromotive force is introduced into the keying circuit **20** after being rectified by a rectifier **19**. This keying circuit **20** controls the degree of conduction of the tone signal coming from the tone generator, in accordance with the intensity of the applied rectified voltage. On the other hand, in case the control circuit shown in FIG. **10** is used, the operation will be as follows. When an electromotive force is generated in the coil **17**, this electromotive force is amplified by the transistor **25** and the resulting electromotive force is derived at the emitter follower of the transistor **30** in the next stage. This voltage is then rectified by the rectifier **32** and is applied to the gate electrode of the FET **33**. The degree of conduction between the source and the drain electrodes of the FET **33** is controlled by virtue of said voltage applied to the gate electrode of the latter transistor **33**. Thus, the output of the tone signal is controlled.

In the electronic musical instrument having the aforesaid structure, arrangement is provided so that the key switch will be actuated at the shallow depressed position of the key **12**. Therefore, when the key **12** is depressed and lowered in its position at a certain speed, there are generated changes in the magnetic flux in the coil **17** in accordance with the stroke of the descending key **12**, as shown in FIG. **11**. Let us assume that the vertical axis represents magnetic flux, and that the horizontal axis represents the stroke of the depressed key. When this downwardly going stroke of the key takes a small value during the initial part of displacement, the magnetic flux will undergo a very great change since the displaceable magnetism-conducting member **15** is positioned close to and faces the coil **17**. Then, as the descending stroke of the key **12** increases in its covering distance, said member **15** will part away from the coil **17**, so that the changes produced in the magnetic flux generated in the coil **17** will progressively decrease. In other words, the electromotive force which is generated in the coil **17** will be the greatest in its intensity in the initial part of the descending movement of the key **12**, and will gradually become smaller as the key **12** is depressed further. Thus, even when the key **12** is depressed only to a shallow depressed position, there will be applied an intensive voltage to either the keying circuit **20** or the gate electrode of the FET **33**, so that the tone signal coming from the tone generator circuit will be transmitted, with a great gain, to the next stage device, and thus, an intensive output is derived. Accordingly, even when the instrument is played in such a manner as if the keys **12** are tapped lightly without depressing them deeply, there will be obtained intensive output sounds, and this will be quite convenient for performances which are conducted at high speeds or for glissando playing. Also, the sound volume will differ between the modes of playing when the keys **12** are depressed to a shallow position and when they are depressed to a deep position. Thus, it is possible to vary the sound volume depending on the manner in which the keys are operated. In this way, it is possible to give a performance rich in variation.

In the electronic musical instrument of the instant embodiment, the displaceable magnetism-conducting member **15** is arranged to face the magnetized core **7** which is inserted in the coil **17** and to be attracted toward the core **7** whenever the key **12** is in its normal stationary position or in a very shallow depressed position. Therefore, the player will feel that the keys are relatively heavy during the initial part of depression applied onto the keys **12** and that the weight of the keys are lessened as they are depressed to deeper positions because of the reducing attractive force between the magnetism-conducting member **15** and the magnetized core **7**. Thus, the key touch of this instrument approaches closer to that of a piano, and the key operation can be carried out smoothly.

The manner in which the coil **17** is wound around the magnetized core **7** and the manner in which the magnetism-conducting member **15** is caused to approach toward or part away from the coil **17** may be modified as required as shown in FIGS. **12***a*, **13***a* and **14***a*, respectively. In the event that the magnetized core **7** is substituted by a non-magnetized magnetic core, this non-magnetized core **7***a* is secured to a magnet M which has been magnetized in the predetermined polar direction, in the manner as shown in FIGS. **12***b*, **13***b* and **14***b*, respectively, to magnetize said core **7***a*. According to this embodiment, it is possible to vary the output sound volume in accordance with the pressure applied onto the keys and thereby to give a performance richer in variation of tone envelope.

Description will hereunder be directed to a still another embodiment. In order to facilitate the description, a keyboard arrangement shown in FIG. **15** is used in which the displaceable magnetism-conducting member **15** is located away from the coil **17** whenever the key **12** is in its normal stationary position. The sound volume control circuit may use the arrangement shown in FIG. **9** or FIG. **10**. Since the operations of these control circuits have been described, their description is omitted. In the instant embodiment, the keyboard structure is provided with a stopper felt **44** on that part of the frame **16** which is located below the leg **14** for regulating the displacement of the key **12**. The magnetized core **7** may be formed so as to have a size such that it has an end facial area smaller than that of the magnetism-conducting member **15** as shown in FIG. **16**. Alternatively, the magnetized core **7** may have a size such that it has an end facial area larger than that of the magnetism-conducting member **15** as shown in FIG. **17**. Or, instead of making these two members **7** and **15** themselves having such sizes that are different relative to each other, there may be provided a small iron pole piece **7***a* at the foremost end of the magnetized core **7** in such a way that this pole piece **7***a* has an end facial area which is smaller than that of the core **7** to which said pole piece **7***a* is securely attached, and that said end facial area of this pole piece **7***a* is smaller than that of the magnetism-conducting member **15**, as shown in FIG. **18**. Conversely, an iron piece **15***a* may be secured to the rear end of the magnetism-conducting member **15** in such a way that said iron piece **15***a* has a smaller end facial area than the foremost end area of the core **7** as shown in FIG. **19**. In FIG. **15**, there is seen an actuator **18** provided below the key **12** for driving a key switch **55** which also is provided below the key **12**.

Since, in this instant embodiment, the magnetism-conducting member **15** and the magnetized core **7** are of end facial areas which are different relative to each other, it will be understood that, as the key **12** is depressed to lower its position at a certain speed, the magnetism-conducting member **15** accordingly will continue to displace its position in such a way that either one of the two members having a smaller end facial area than that of the other of the two members will continuously face said other of the members having a larger end facial area during the period from the time the magnetism-conducting member **15** starts facing the magnetized core **7** contained in the coil **17** till the key **12** completes the descension. Thus, there will arise hardly any change in the density of the magnetic flux generated in the coil **17** during the aforesaid period, and accordingly, no voltage is produced. The density of the magnetic flux will progressively increase from the starting of the downward key stroke as shown in FIG. **20***a*. However, in a certain range of the stroke in its final stage, the magnetic flux will have a substantially constant density as indicated A—A. Accordingly, even if the stopper felts **44**, for example, which are provided on the keys **12** may have thicknesses slightly different from each other, because of a slight lack of precision in the aligning of the magnetism-conducting member **15** relative to the magnetized core **7** which is contained in the coil **17** at the time the musical instrument is fabricated, the magnetism-conducting member **15** will, whenever the key **12** is depressed up to its lowermost position, always be rendered to the state in which it faces the core **7**. Thus, there will arise no such inconvenience that the density of the magnetic flux undesirably changes owing to the variance in the lowermost positions of the keys **12**. Accordingly, the operation of the keys **12** will always be performed with surety.

In contrast to the above-described arrangement of the keyboard, if the assembly of the coil **17** and the core **7** is arranged so that it faces the magnetism-conducting member **15** whenever the key **12** is in its normal stationary position, it will be understood that the magnetic flux will have a substantially constant density A—A in the initial part of the downward key stroke, and thereafter the density will undergo changes so as to gradually decrease, as shown in FIG. **20***b*. Accordingly, during the starting of depression of the key **12**, i.e., when the density is A—A, there is produced no voltage. However, when subsequently the magnetism-conducting member **15** no longer faces the magnetized core **7**, there is obtained an intensive output which will gradually become smaller. Accordingly, in this example of the keyboard arrangement, there will arise no change in the density of the magnetic flux from a slightly lowered position of the key **12** when the player of the instrument begins depression of the key **12**. For example, even when there occurs a slight mis-touch onto a key **12** during playing, there will appear no effect of such a mis-touch. Nor will there hardly appear an effect from a bouncing of the key **12** which may take place when this key **12** returns to its normal stationary position from its depressed position. The rest of the operation of this instrument is practically the same with that described in connection with the preceding embodiments.

Description will hereunder be made on yet another embodiment of the present invention. As shown in FIG. 21*a*, each of the white (natural) keys **12** and the black (sharp) keys **12***a* is supported at a fulcrum **11***a* of a supporting rod **11** near the rear end of the key **12** so that the key may be able to be freely pivoted downwardly. As in the preceding embodiments, a spring **13** is provided at the rearmost end of each of keys **12** and **12***a* so that the keys are allowed to return to their normal stationary positions which may, for example, horizontal. The white and the black keys **12** and **12***a* each has a leg **14** which extends downwardly from the lower surface thereof near the foremost end in such a way that the legs **14** are aligned in a row. The portion of the length of the black key **12***a* extending from the site at which it is supported till the foremost end is smaller than the length of the white key **12**. The leg **14** of each of these black keys **12***a* projects downwardly from the foremost end. The portion of the length of the white key **12** extending from the site at which it is supported till the foremost end is longer than the length of the black key **12***a*. The leg **14** of each of these white keys **12** projects downwardly from a site near the foremost end so as to be aligned in a row relative to the leg **14** of the black key **12***a*. This leg **14** of each of the white and the black keys **12** and **12***a* is formed so that it has a recumbent U-shape in that portion of the leg extending longitudinally from substantially the middle to the lowermost end. More specifically, the leg **14** has a recess **66** formed in the front side as shown in FIG. 21*b*. A magnetism-conducting member **15** is secured to the leg **14** at the lowermost end of the recess **66**. The extension of the leg **14** adjacent said recess **66** passes through an opening **181** formed in the frame **16**. A stopper felt **182** is provided on the frame **16** at a position below said leg portion **14**. Said recess **66** of said leg **14** is adapted to engage said stopper felt **182** so that the pivotal movements of the keys **12** and **12a** are limited by said stopper felt **182**. A coil **17** is secured to an inverted U-shaped supporting frame **191** connected to the underside of the aforesaid supporting frame **16**. This coil **17** is arranged at a position below said frame **16** close to said leg **14** between the rear end face of said leg **14** and said supporting rod **11**. A magnet core or a core **7** which has been magnetized by some other magnet is securely contained in said coil **17**. This assembly of the core **7** and the coil **17** is arranged so that, when the key **12** or **12***a* descends, the forward end of the core **7** will face the aforesaid magnetism-conducting member **15**. An actuator (not shown) for driving the key switch (not shown) is provided below each of said key **12** and the key **12***a*.

The keying control circuit which can be employed may be either one of the previously described circuitries shown in FIGS. **2** and **3**. The operations of these circuitries have been already described, and therefore, their descriptions are omitted.

According to this instant embodiment, the displaceable magnetism-conducting member **15** is provided at a position remotest from the fulcrum **11***a* on the condition that the respective magnetism-conducting members **15** are aligned in a row for both the white keys **12** and the black keys **12***a*. By virtue of this arrangement of the displaceable magnetism-conducting members **15**, they are allowed to exercise strokes within a considerably large distance. This gives the advantages and conveniences that there are produced very clear changes in the magnetic flux in the coil **17** which is wound around the core **7**, and that trill playing may be performed with easiness and further that a slight lack of precise relative positioning of the magnetism-conducting member **15** and the coil **17** will hardly cause any problem in the sound operation of the keyboard arrangement. The advantages of this instant embodiment also include the fact that it is easy to provide a known key switch in the space thus formed between the fulcrum **11***a* and the leg **14**, and that the magnetism-conducting member **15** which is secured to the key **12** or key **12***a* greatly contributes to increasing the weight of the key **12** or key **12***a* per se to obtain a better touch control which is close to that of the keys of a piano. A further advantage of this embodiment is that, in view of the magnetism-conducting member **15** being secured to the extension of the leg depending downwardly from the key **12** or **12***a* and in view of the coil **17** being secured to the supporting frame **191** which is provided below the frame **16**, it greatly enhances the workability with respect to making the electrical connection of the lead wire extending from each coil **17**.

In the above described embodiment, the magnetism-conducting member **15** is attached to the lowermost end of the extension of the leg **14**. It should be understood that the member **15** may be secured at an intermediate portion or an upper portion of the leg **14**. To comply with such a modified arrangement of the member **15**, the coil **17** may be provided on the upper side of the supporting frame **16**. The manner in which the coil **17** is wound around the magnetized core **7** and the manner in which the magnetism-conducting member **15** is caused to approach toward or part away from the coil **17** may be modified in various ways as shown in FIGS. **22***a*, **23***a* and **24***a*. Also, the magnet which serves as the magnetized core **7** may be substituted by a non-magnetized magnetic core **7***a*. In such an instance, this latter core **7***a* is secured to a magnet M which has already been magnetized to have a predetermined polar direction in such a manner as shown in FIGS. **22***b*, **23** *b* and **24***b* to thereby magnetize said non-magnetized core **7***a*.

Description will hereunder be directed to a further embodiment of the present invention. The keyboard arrangement shown in FIG. **25** is practically the same as that shown in FIG. **1** with only the following exceptions.

A resilient member **15***a* which is made of a piece of material such as rubber, sponge or felt, is secured to the lower face of the magnetism-conducting member **15**. This arrangement of the keyboard is very convenient for trill playing. Even when there arises a slight mistouch, there will not be produced any audible sound of music from a slight key touch. Besides, the instant arrangement is such that, when the key **12** is depressed or struck with a great pressure, the key **12** will be caused to be brought into contact with the core **7** with the intervention of the resilient member **15***a* therebetween. Accordingly, there will never be produced any mechanical noise at the time that these two members are brought into contact. Also, the magnetism-conducting member **15** will part away from the core **7** rapidly owing to the resiliency of the resilient member

15*a*. Thus, there will arise no such an inconvenience as will hamper the sound and smooth operation of the keys. In addition, by appropriately selecting the thickness of the resilient member **15***a*, it is possible to make the distance between the magnetism-conducting member **15** and the core **7** minimal at the time the key **12** is depressed to substantially increase the intensity of the electromotive force generated in the coil **17** and to thereby greatly enhance the touch-responsive control of the instrument.

FIG. **26** shows the manner in which the magnetic flux passing through the coil **17** changes. As will be understood from this distribution chart, the magnetic flux undergoes a small change during the initial part of the movement of the key **12** from the time at which the key **12** starts displacement from the normal stationary position till the magnetism-conducting member **15** assumes a position in which it faces the coil **17**, and the magnetic flux undergoes a substantial change toward the end of the movement of the key **12**. In the coil **17**, there is generated an electromotive force whose intensity is in compliance with the changes in the magnetic flux.

The manner in which the coil **17** is wound around the magnetized core **7** and the manner in which the magnetism-conducting member **15** is caused to approach toward and part away from the coil **17** may be modified as required as shown in FIGS. **27**, **28***a* and **29***a*. In case the magnet serving as the magnetized core **7** is substituted by a non-magnetized magnetic core **7***a*, this latter core **7***a* is secured to a magnet M which has been already magnetized so as to have a predetermined polar direction in a manner as shown in FIGS. **28***b* and **29***b*, to thereby magnetize said core **7***a*. Also, the resilient member **15***a* which is secured to the magnetism-conducting member **15** may be secured to the uppermost end of the core **7** or **7***a*.

Description will hereunder be made on a still further embodiment of the present invention.

An example of the keyboard arrangement is shown in FIG. **30**, which is practically the same as that of the preceding embodiment with the following exceptions. A magnetism-conducting rubber piece **15** (i.e. a resilient magnetically permeable material) which is made with a rubber or a synthetic rubber containing particles of soft iron or like magnetic material scattered therein is secured to the lower surface of the key **12** at a site close to the leg **14** which extends downwardly from the lower face of the key **12**. Either one of the keying control circuits shown in FIG. **2** and FIG. **3** may be connected to the coil **17**.

FIG. **31** shows the distribution chart of the magnetic flux passing through the coil **17** as the key **12** is depressed. Since the manner in which the changes in the magnetic flux take place is the same as that for the preceding embodiment, its description is omitted. It is to be noted that this arrangement of the keyboard is suitable for trill playing as in the preceding case. Also, a slight mis-touch will not be manifested in audible sounds.

Besides, the attachment of the magnetism-conducting rubber piece **15** to the key **12** will increase the weight of the key **12** as a whole to a desirable extent so that the touch sentiment will be improved. In the instant embodiment, the magnetism-conducting rubber piece **15** is arranged so that it will be brought into contact with the magnetized core **7** when the key **12** is depressed to assume a deeply lowered position. Accordingly, there will be produced no mechanical noise when these two members are brought into contact with each other. Also, this magnetism-conducting rubber piece **15** will rapidly part away from the core **7** by virtue of its own resiliency after the rubber piece **15** has struck the core **7** at its upper face, so that the key depressing operation will be performed without any difficulty. In addition, according to this embodiment, the gap between the rubber piece **15** and the core **7** at the time of depression of the key **12** can be minimized, so that it is possible to increase the intensity of the electromotive force which is generated in the coil **17** at such a time. Thus, it is possible to enhance the touch-responsive control of the instrument.

The manner in which the coil **17** is wound around the magnetized core **7** and the manner in which the magnetism-conducting rubber piece **15** is caused to approach toward and part away from the coil **17** can be modified as required as shown in FIGS. **32**, **33***a* and **34***a*. The magnet which constitutes the magnetized core **7** may be substituted by a non-magnetized magnetic core **7***a*. In such an instance, the core **7***a* may be secured to a magnet M which has been already magnetized to have a predetermined polar direction as shown in **33***b* and **34***b* to thereby magnetize the core **7***a*. The magnetism-conducting rubber piece **15** may be substituted by a soft iron piece or like magnetic material which conducts magnetism. In such a case, the core **7** or **7***a* may be made with a magnetic rubber or a magnetized rubber to obtain the same effect as that described in connection with the preceding embodiment.

I claim:

1. A keyboard device for an electronic musical instrument, said device comprising:

a plurality of hinged movable keys arranged in juxtaposed relationship to each other on a frame which is fixed with respect to said instrument,

a first substantially non-magnetized member of magnetically permeable material associated with each of said keys and attached to its corresponding key for movement therewith, and

a second magnetized means associated with each of said keys and immovably secured to said frame for producing an electrical output related to the intensity of depression imparted to its respectively associated key, said second magnetized means comprising;

a fixed core of magnetic material having a quiescent magnetic flux therein, said core having an end face disposed to achieve substantially opposing confrontation with an end face of a respectively corresponding one of said non-magnetized members when the associated key is in a predetermined position, and

an electrical winding on said core to detect the rate of change of magnetic flux therein in response to relative motion between the respectively associated core and non-magnetized member.

2. A keyboard device as in claim **1** wherein said predetermined position of the key is an undepressed position whereby relatively great magnetic flux changes are produced during the early stages of key depression.

3. A keyboard device as in claim 2 wherein said end face of said core has an area dimension different from the area dimension of said end face of said non-magnetized member whereby slight positioning inaccuracies in achieving the desired opposing confrontation of the end faces are not critical to the proper functioning of the device in that such inaccuracies do not materially change the maximum magnetic coupling between the non-magnetized member and the core at said predetermined key position.

4. A keyboard device as in claim 1 wherein said second magnetized means includes a common elongated permanent magnet means for simultaneously producing said quiescent magnetic field in a plurality of adjacent ones of said cores.

5. A keyboard device as in claim 1 wherein said fixed cores comprise permanent magnets.

6. A keyboard device as in claim 1 wherein said first non-magnetized member comprises a resilient magnetically permeable material.

7. A keyboard device as in claim 1 further comprising resilient means interposed between said end faces whereby actual contact between said faces is prevented to eliminate undersirable noise and to help facilitate separation of said end faces when the associated key is moved from said predetermined position.

8. A keyboard device for an electronic musical instrument, said device comprising:

a plurality of keys swingably supported and arranged in juxtaposed relationship, each of said keys having a projecting leg member to define its swingable movement, and

first and second means associated with each of said keys and magnetically cooperating with each other for producing an electromotive force in proportion to the speed at which they move away from each other,

said first means being a magnetism-conducting member which is attached to said projecting leg member of its respectively associated key,

said second means being a coil wound around a core of magnetic material having a quiescent magnetic flux therein and which second means is disposed to place said first and second means at positions where they are relatively most closely disposed to each other when said respectively associated key is in an undepressed position, and wherein said first and second means move away from each other when said respectively associated key is depressed.

9. The keyboard device as in claim 8, wherein:

said magnetism-conducting member and said core both have respective end faces which opposingly confront each other in at least one key position

said end face of said magnetism-conducting member being different in size from said end face of said core whereby slight positioning inaccuracies in achieving the desired opposing confrontation of the end faces will not substantially affect the magnetic coupling therebetween and therefore not be critical to the proper functioning of the device.

10. A keyboard device as in claim 9 wherein said second means includes a common elongated permanent magnet means for simultaneously producing magnetic fields in a plurality of adjacent ones of said cores.

11. A keyboard device for an electronic musical instrument, said device comprising:

a plurality of keys swingably supported and arranged in juxtaposed relationship, and

first and second means associated with each of said keys and magnetically cooperating with each other for producing an electromotive force in proportion to the speed at which they approach and move away from each other,

said first means being a magnetism-conducting member which is attached to its respectively associated key,

said second means being a coil wound around a core of magnetic material having a quiescent magnetic flux therein,

said magnetism-conducting member and said magnetized core both having respective end faces which opposingly confront each other in at least one key position,

said end face of said magnetism-conducting member being different in size from said end face of said core whereby slight inaccuracies in positioning said end faces for confronting dispositions is not critical to the proper functioning of the device.

12. A keyboard device as in claim 11 wherein said second means includes a common elongated permanent magnet means for simultaneously producing magnetic fields in a plurality of adjacent ones of said cores.

* * * * *