United States Patent

Ohno

[15] **3,652,774**

[45] **Mar. 28, 1972**

[54] KEYING SYSTEM FOR ELECTRONIC MUSICAL INSTRUMENTS

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

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

[22] Filed: **Oct. 15, 1970**

[21] Appl. No.: **80,937**

[30] **Foreign Application Priority Data**

Oct. 16, 1969	Japan	44/82723
Oct. 16, 1969	Japan	44/82724
Oct. 16, 1969	Japan	44/82725
Oct. 16, 1969	Japan	44/82726
Oct. 20, 1969	Japan	44/83638
Oct. 20, 1969	Japan	44/84424
Oct. 22, 1969	Japan	44/100402
Oct. 22, 1969	Japan	44/100403
Oct. 24, 1969	Japan	44/85055
Oct. 24, 1969	Japan	44/85056
Oct. 24, 1969	Japan	44/85057
Oct. 24, 1969	Japan	44/85058

[52] **U.S. Cl.** **84/1.24**, 84/1.26, 84/DIG. 7

[51] **Int. Cl.** **G10h 1/02**

[58] **Field of Search** ..... 84/1.01, 1.24, 1.26, DIG. 7, 84/1.21, 1.27

[56] **References Cited**

UNITED STATES PATENTS

3,564,105	2/1971	Amano	84/1.01
2,296,125	9/1942	Traub	84/1.27
2,848,920	8/1958	Lester	84/1.27
3,463,867	8/1969	Pavig	84/1.21
3,507,970	4/1970	Jones	84/1.01
3,544,695	12/1970	Dijksterhuis	84/1.26
3,567,839	3/1971	Dijksterhuis	84/1.26

Primary Examiner—Thomas J. Kozma
Assistant Examiner—Ulysses Weldon
Attorney—Cushman, Darby & Cushman

[57] **ABSTRACT**

In an electronic musical instrument having playing keys of a keyboard and associated keyer circuits, the effect of double-control can be obtained by the provision of a keying system including first and second keyer controllers provided for each key to control the respective keyers. The first keyer controller is operative for normal key depression stroke prior to the key's lowest position, while the second keyer controller is responsive to a depressing force applied to the key during its stay at the lowermost end of its stroke.

22 Claims, 37 Drawing Figures

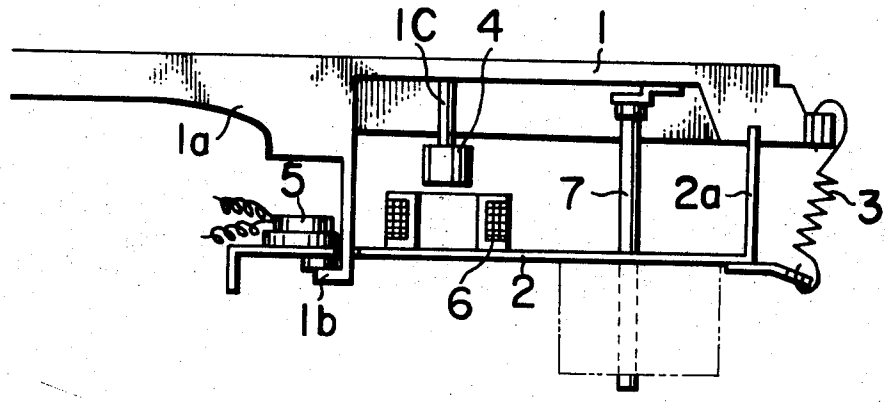


FIG. 1

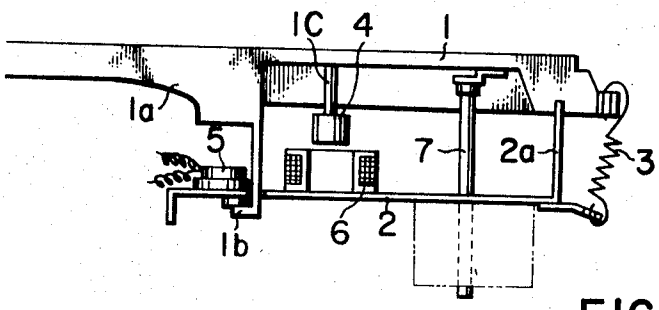


FIG. 2

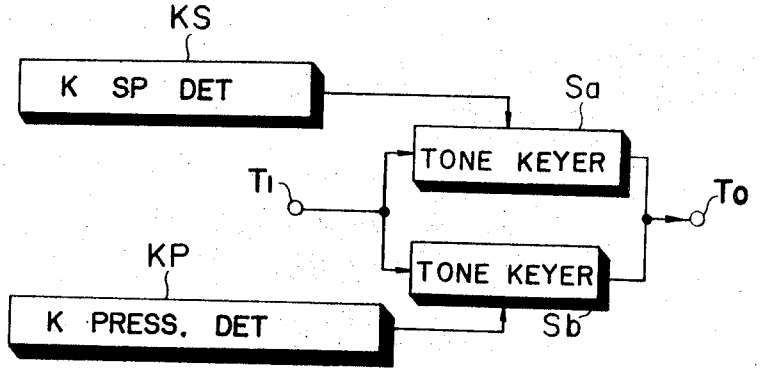


FIG. 3

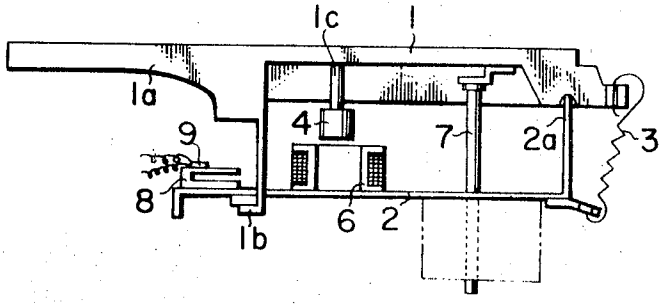


FIG. 4

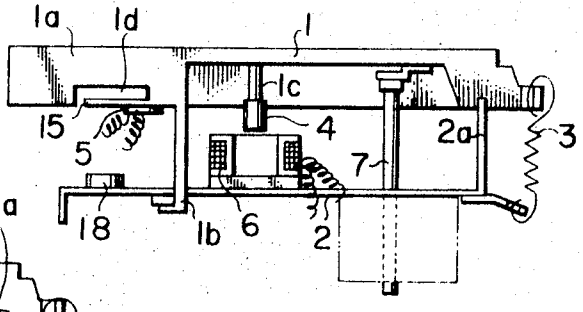
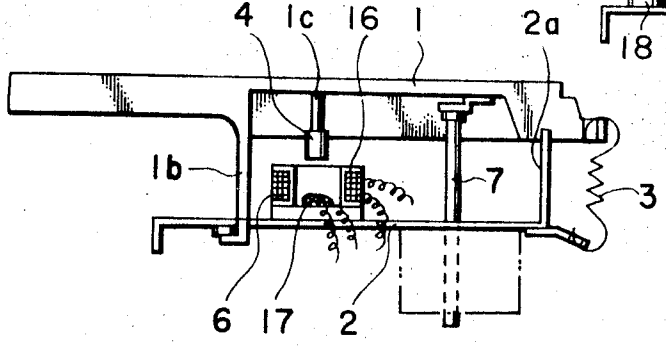


FIG. 5



INVENTOR.
Junji OHNO
BY
Cushman, Darby & Cushman
ATTORNEYS

FIG. 6a

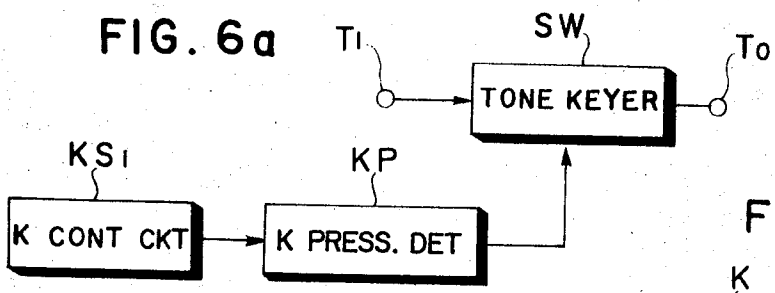


FIG. 6b

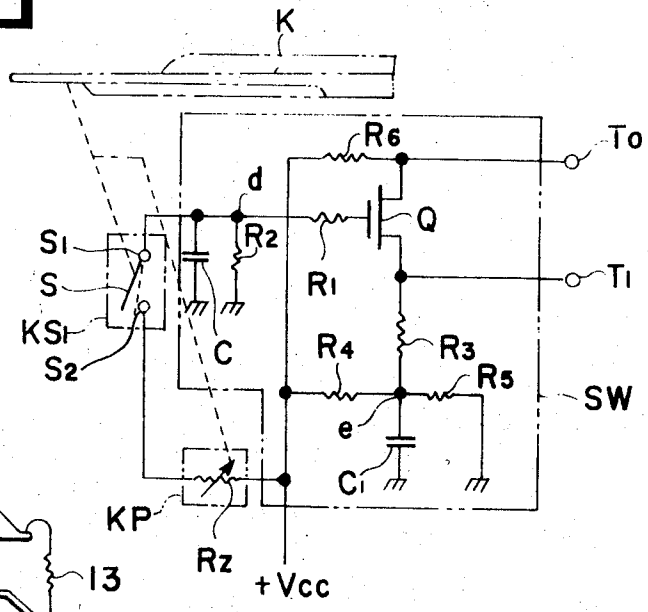


FIG. 6c

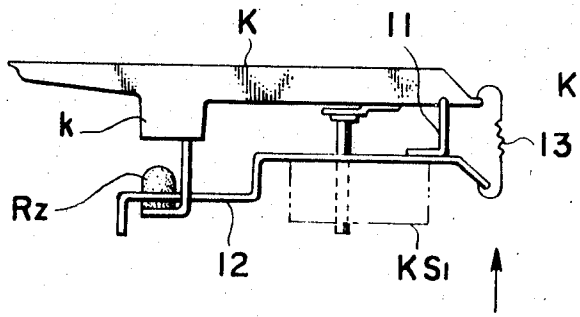


FIG. 6d

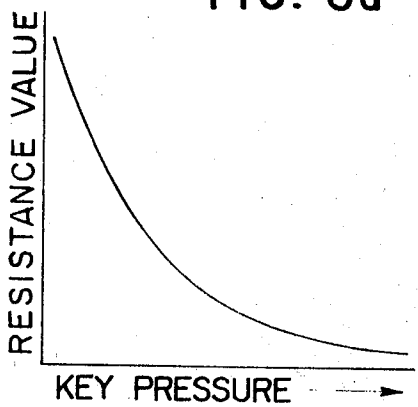
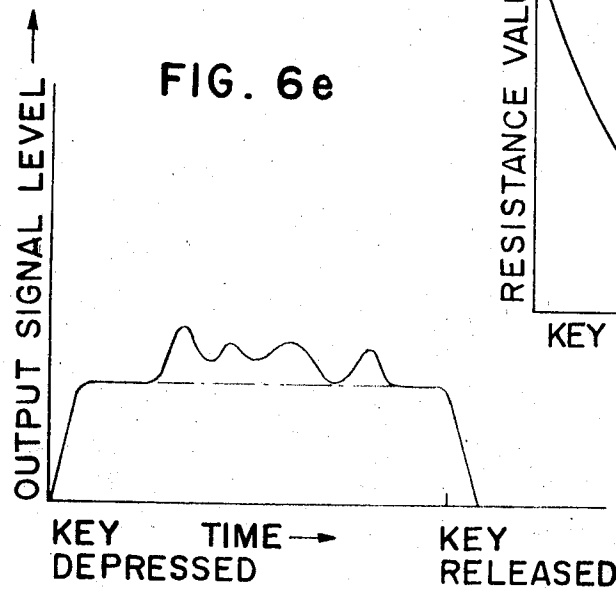


FIG. 6e



INVENTOR.
Junji OHNO
BY
Cushman, Darby & Cushman
ATTORNEYS

FIG. 7a

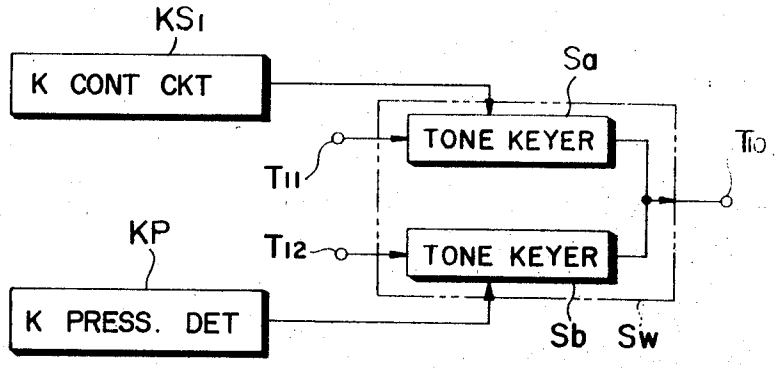


FIG. 7b

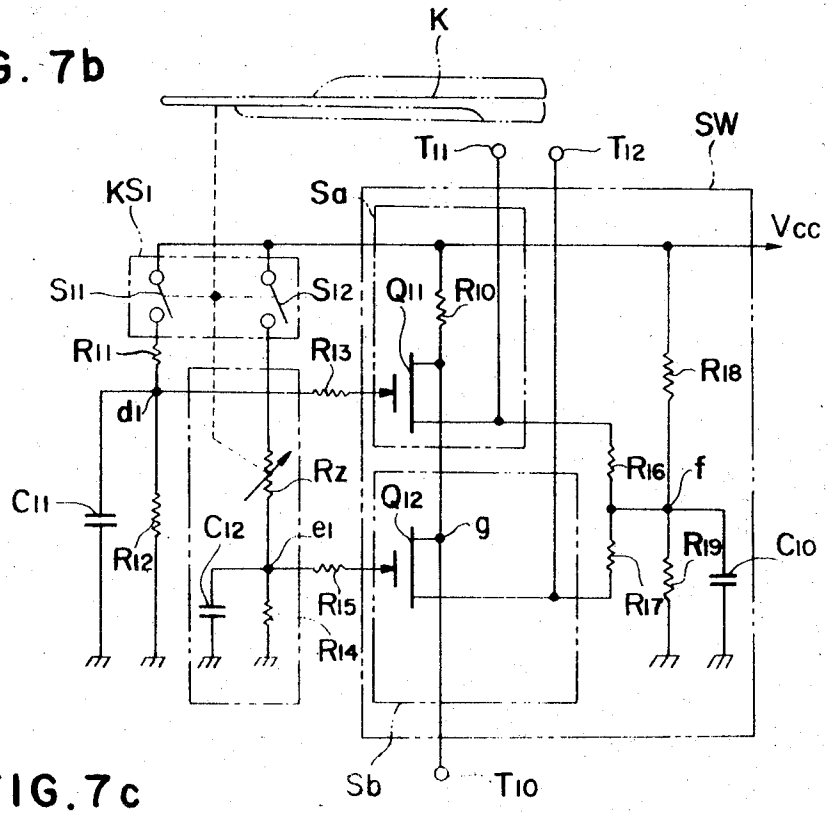
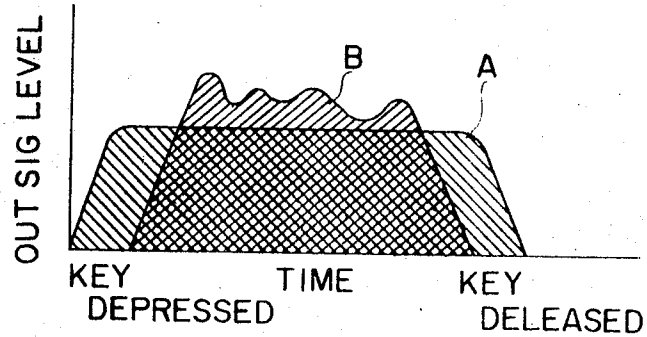


FIG. 7c



INVENTOR.
Junji OHNO
BY
Cushman Darby & Cushman
ATTORNEYS

FIG. 8a

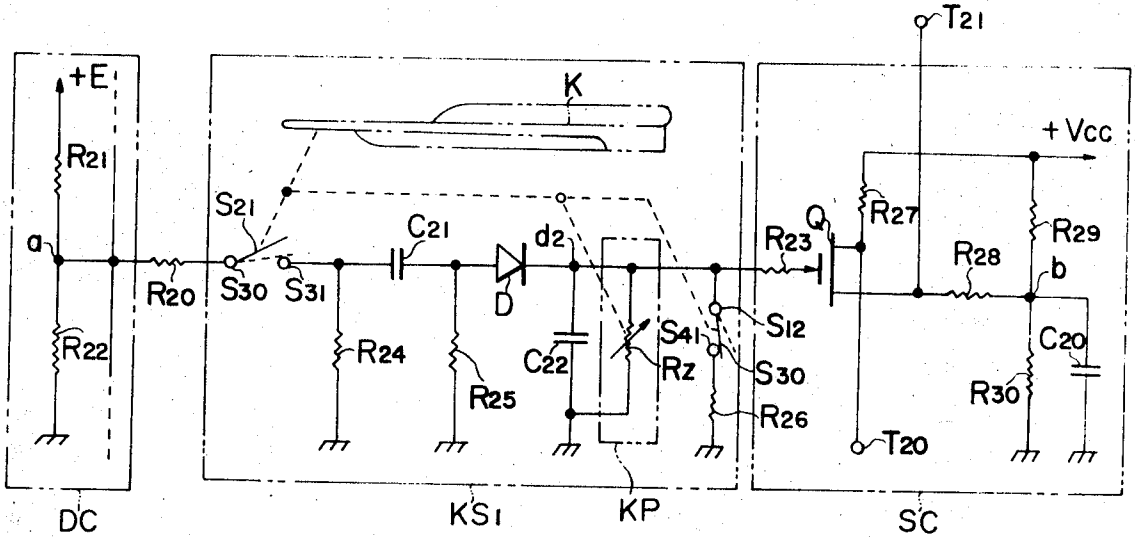


FIG. 8b

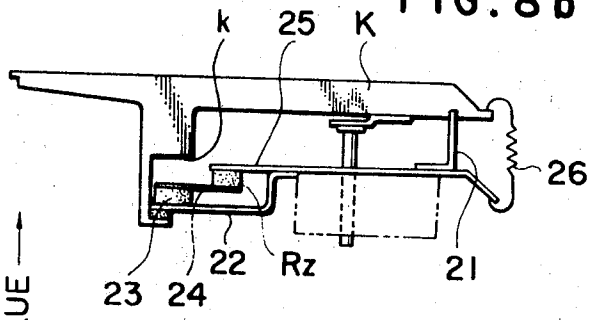


FIG. 8e

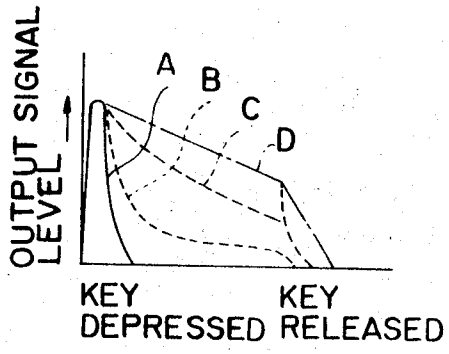


FIG. 8c

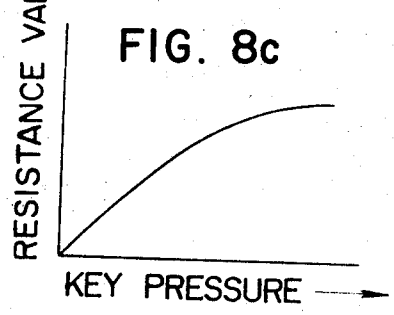
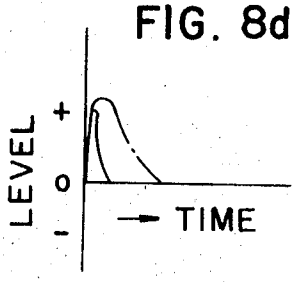


FIG. 8d



INVENTOR.
Junji OHNO
BY
Cushman, Darby & Cushman
ATTORNEYS

FIG. 9a

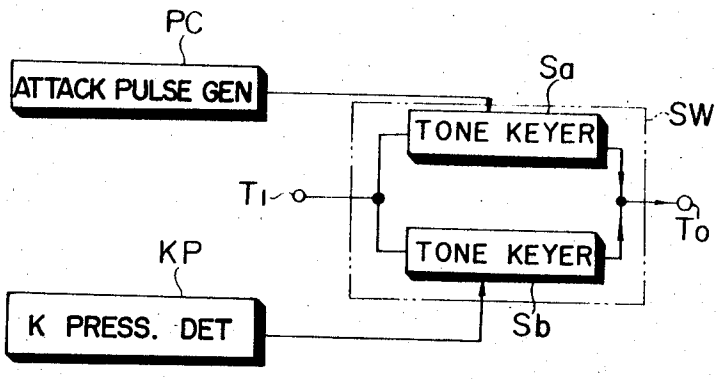


FIG. 9c

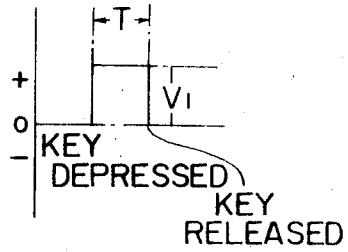


FIG. 9d

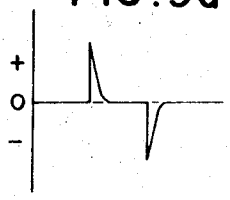


FIG. 9e

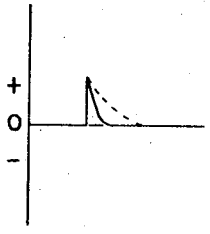
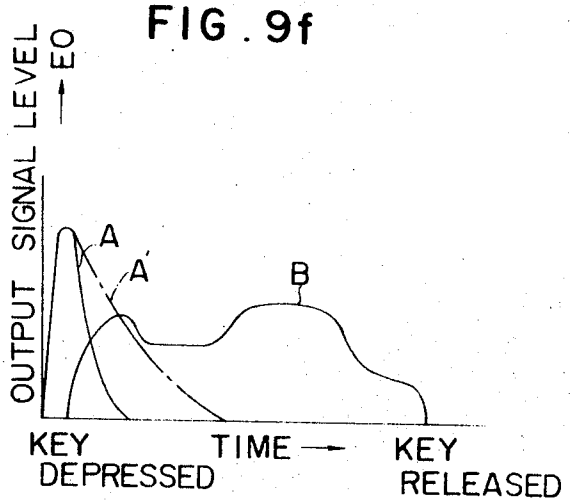


FIG. 9f



INVENTOR.

BY Junji OHNO

Cushman, Darby & Cushman

ATTORNEYS

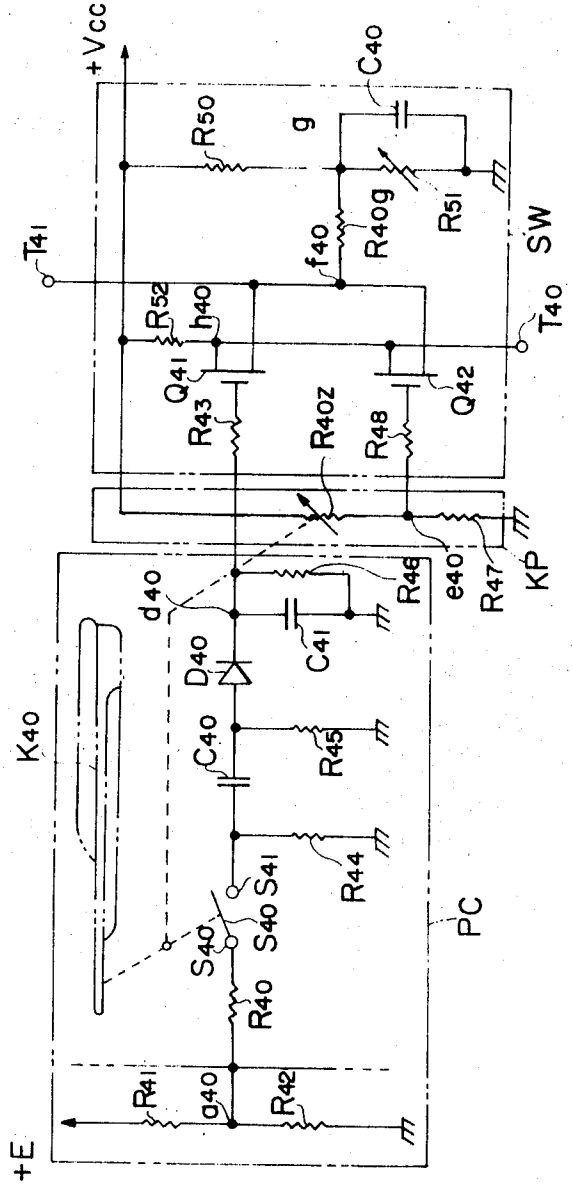


FIG. 9b

INVENTOR.

BY Junji OHNO

Cushman, Darby & Cushman

ATTORNEYS

FIG. 10a

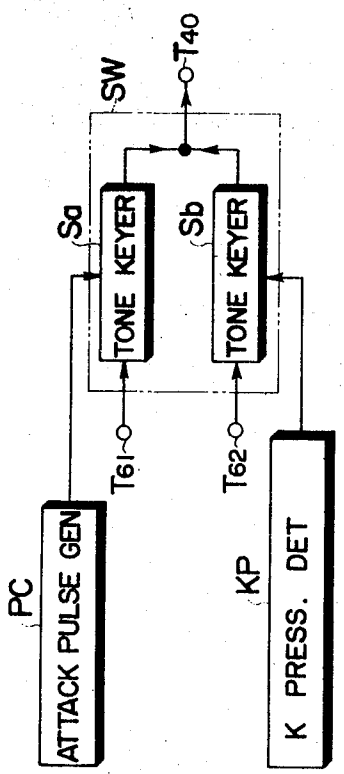
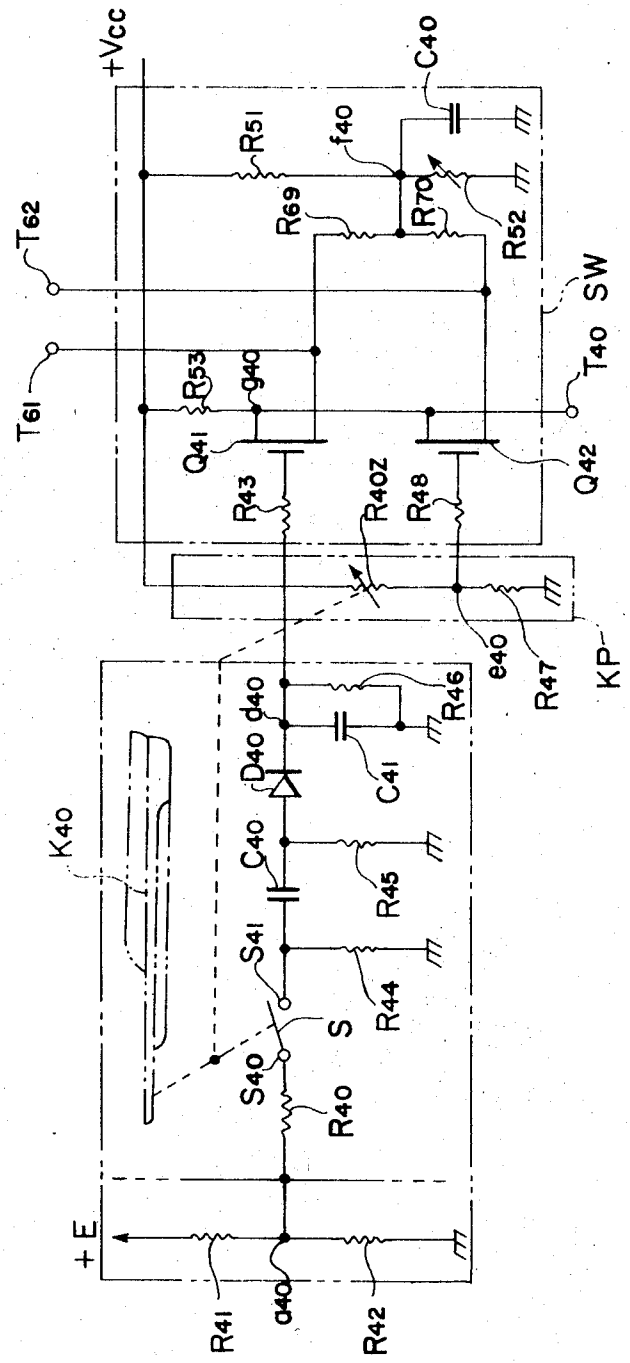


FIG. 10b



INVENTOR.

Junji OHNO

BY

Cushman, Darby & Cushman

ATTORNEYS

FIG. 11a

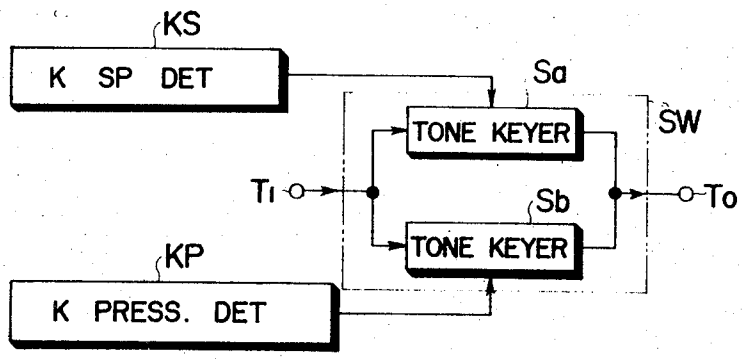


FIG. 11b

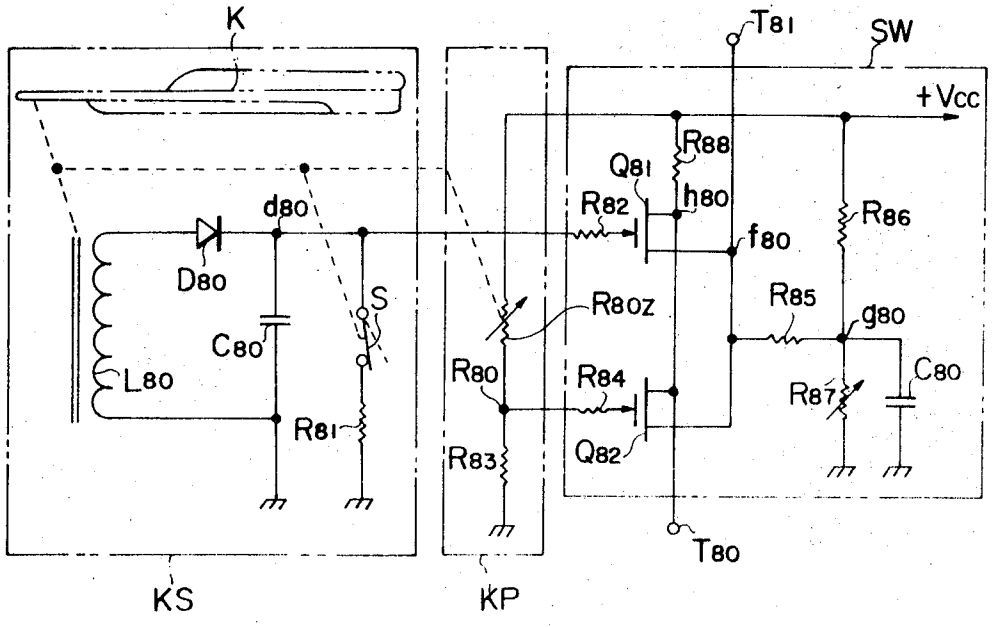
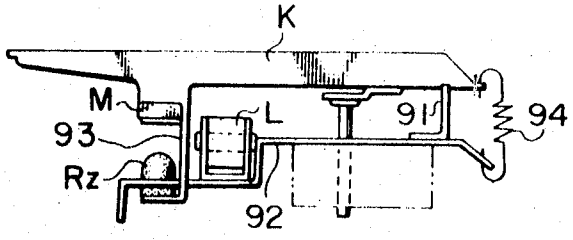


FIG. 11c



INVENTOR.
Junji OHNO
BY
Cushman, Darby & Cushman
ATTORNEYS

FIG. 12a

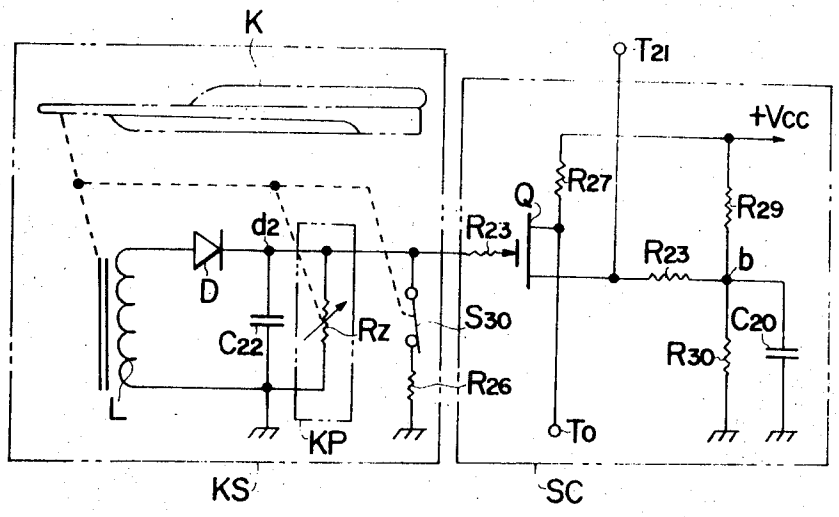


FIG. 11d

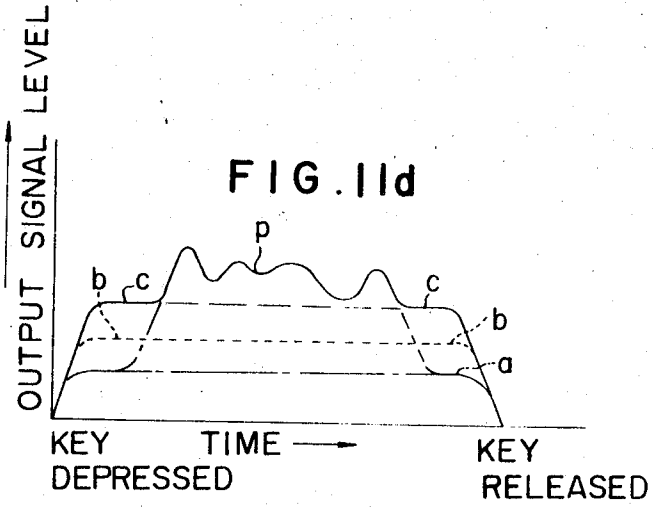
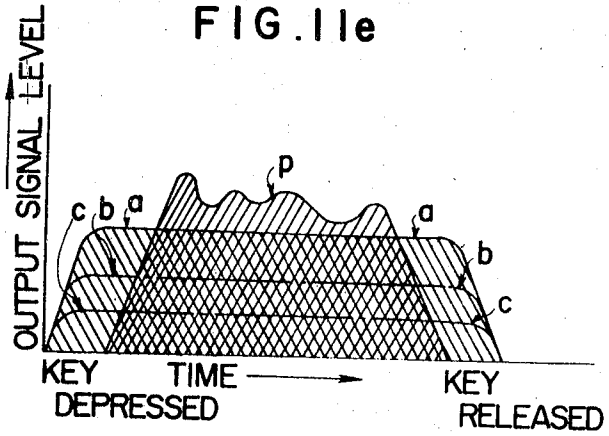


FIG. 11e



INVENTOR.
Junji OHNO
BY
Cushman, Darby & Cushman
ATTORNEYS

FIG. 12b

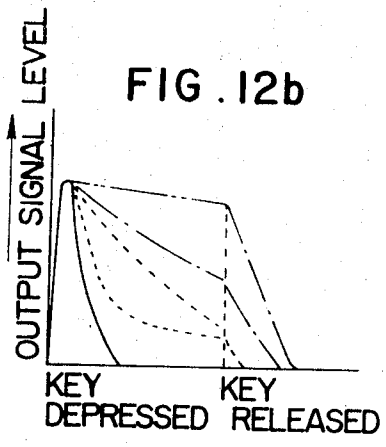


FIG. 12c

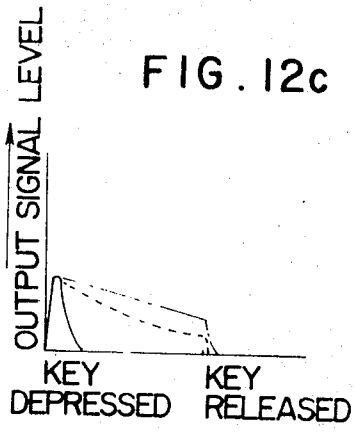


FIG. 13a

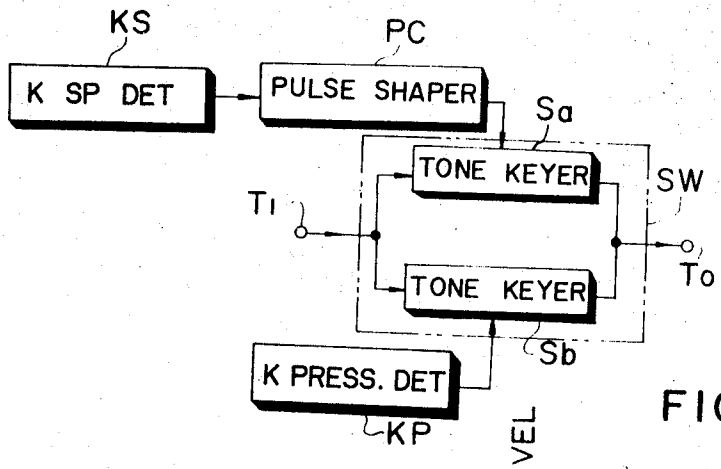


FIG. 13b

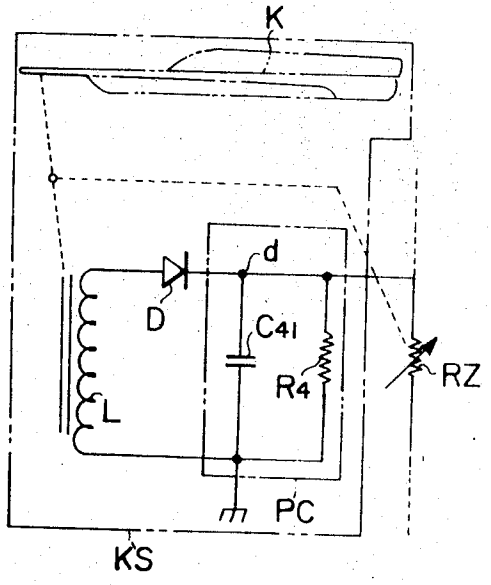
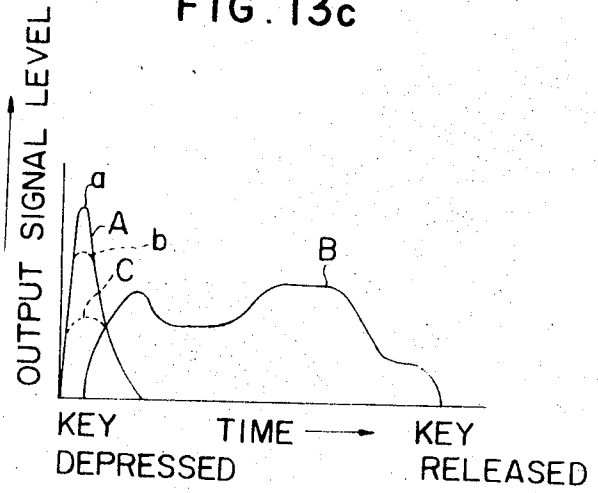


FIG. 13c



INVENTOR.

BY Junji OHNO

Cushman, Darby & Cushman

ATTORNEYS

KEYING SYSTEM FOR ELECTRONIC MUSICAL INSTRUMENTS

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention is concerned with electronic musical instruments, and more particularly it relates to keying system for electronic musical instrument having playing keys, which is capable of making double control of the keyer associated with the key and operable during the depression of this key.

2. Description of the Prior Art

In the conventional electronic musical instrument, tonal effects once produced from depression of a key could not be further controlled at all by the operator. That is, once a playing key for keying a keyer provided for each key in associated relation therewith is depressed by the operator, the keyer which is thus actuated can no longer be controlled by any key depressing action. That is to say, according to the instrument of the prior art, it was impossible to make the so-called "after-control" which means that the tone envelope produced from a normal key depression can be additionally varied in its mode by a further operation of the once-depressed key. For this reason, there was encountered the inconvenience in the past that no desired delicate tonal effects of the music being played could be obtained once a key was depressed.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a novel keying system for an electronic musical instrument, which is capable of making "after-control" to produce delicate tonal effects according to the desire of the person who plays the instrument.

Another object of the present invention is to provide a novel keying system for the instrument of the type described, said system having first and second keyer control means capable of performing double control, i.e., being operative successively in accordance with a normal and a subsequent further depression of an associated key.

A still another object of the present invention is to provide a novel keying system for the instrument of the type described and capable of producing combined tone envelopes as required.

A further object of the present invention is to provide a novel keying system for the instrument of the type described and capable of combining tone signals different from each other by virtue of an initial controller and a subsequent controller both of which are associated with the same playing key.

Another object of the present invention is to provide a novel keying system for the instrument of the type described and capable of controlling the decay time or amplitude characteristics of a percussive signal and/or an attack signal.

Yet another object of the present invention is to provide a novel keying system for the instrument of the type described and capable of producing the so-called touch-responsive tone envelope effect such that a keyed tone signal has an amplitude in accordance with the intensity of depression of an associated key, as well as the so-called "after-control" effect such that the keyer is controlled in accordance with a further depression applied to the playing key after normal depression of the same.

Other objects, features and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a somewhat diagrammatic side elevation, partly in section, of a keyboard of an electronic musical instrument, showing an embodiment of the present invention;

FIG. **2** is a schematic block diagram, showing the novel keying system embodying the present invention for use in the instrument;

FIG. **3** is a somewhat diagrammatic side elevation, partly in section, of the keyboard according to another embodiment of the present invention;

FIGS. **4** and **5** are similar views of the keyboard, showing further embodiments of the present invention, respectively;

FIGS. **6***a* through **6***e* illustrate another embodiment of the present invention, in which: FIG. **6***a* is a schematic block diagram of the novel keying system embodying the present invention; FIG. **6***b* is a circuit diagram associated with a playing key and showing an example of FIG. **6***a;* FIG. **6***c* is a somewhat diagrammatic side elevation, partly in section, of an essential portion of the keyboard for said example; and FIGS. **6***d* and **6***e* are charts for explaining the function of the said keying system;

FIGS. **7***a* through **7***c* are illustrations of the novel keying system according to a still further embodiment, in which: FIG. **7***a* is a schematic block diagram showing this embodiment; FIG. **7***b* is a circuit diagram associated with a playing key and showing an example of FIG. **7***a;* and FIG. **7***c* is a chart for explaining the function of this embodiment;

FIGS. **8***a* through **8***e* are illustrations of another embodiment of the present invention, in which: FIG. **8***a* is a circuit diagram associated with a playing key; FIG. **8***b* is a somewhat diagrammatic side elevation of an essential portion of the keyboard for this embodiment; and FIGS. **8***c* to **8***e* are charts for explaining the function of this embodiment;

FIGS. **9***a* through **9***f* are illustrations of still another embodiment of the present invention, in which: FIG. **9***a* is a schematic block diagram showing this embodiment; FIG. **9***b* is a circuit diagram showing an example of FIG. **9***a;* and FIGS. **9***c* to **9***f* are charts for explaining the function of this system;

FIG. **10***a* is a block diagram showing another embodiment of the present invention, and FIG. **10***b* is a circuit diagram showing an example of FIG. **10***a;*

FIGS. **11***a* through **11***e* are illustrations showing a further embodiment of the present invention, in which: FIG. **11***a* is a schematic block diagram showing this embodiment; FIG. **11***b* is a circuit diagram associated with a playing key and embodying an example of FIG. **11***a;* FIG. **11***c* is a somewhat diagrammatic side elevation of an essential portion of the keyboard for this embodiment; and FIGS. **11***d* and **11***e* are charts for explaining the function of mainly this embodiment;

FIG. **12***a* is a circuit diagram associated with a playing key and showing a still further embodiment of the present invention; FIGS. **12***b* and **12***c* are charts for explaining the function of mainly this embodiment;

FIG. **13***a* is a schematic block diagram of another embodiment of the present invention; FIG. **13***b* is a circuit diagram associated with a playing key and showing a modification of FIG. **9***a;* and FIG. **13***c* is a chart for explaining the function of mainly this embodiment.

In the drawings, like references and symbols indicate like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Description of the present invention will be made on several embodiments by referring to the accompanying drawings.

Referring to FIGS. **1** and **2**, there is shown a basic embodiment of the present invention, in which numeral **1** represents one of a plurality of playing keys contained in the keyboard and spaced with a required distance from a frame **2**, each key **1** been pivotally supported by a support **2***a* extending upright from the rear end of the frame **2**. Between the rear end of the key **1** and the frame **2**, there is provided a tension spring **3** to normally keep the key in the normal horizontal position. At the bottom surface of the forward portion of the key **1**, there are provided a shouldered portion **1***a* for applying a pressure force onto a pressure-sensitive resistance element **5** which will be described later and which is provided therebelow on the forward portion of the frame **2**, and a stopper **1***b* provided on the downward extension of the shouldered portion **1***a* for limiting the upward movement of the key **1** to thereby normally hold the key in place.

From the bottom face of an intermediate portion of the key **1** behind the shouldered portion **1***a*, there extends downwardly a lever **1***c*. A magnet **4** is secured to the lower end

of this lever 1*c*. The pressure-sensitive resistance element **5** — which may be a piece of electroconductive rubber, a pressure-sensitive diode or the like — is provided on the upper side of the frame **2** so as to face said shouldered portion **1***a* at a predetermined interval therebetween. A coil **6** is wound around a bobbin located on the frame **2** behind the extension of the shouldered portion **1***a* to face the magnet **4** at a predetermined interval therebetween. The shouldered portion **1***a* is arranged so that it is brought into contact with the pressure-sensitive resistance element **5** at substantially the lowermost end position of the key's normal stroke. Further, an actuator **7** for actuating a key-switch which is seen as a block defined by a phantom line in FIG. **1** is mounted, for vertical movement, on the bottom of the key **1** so as to pass through the frame **2**.

The coil **6** and the pressure-sensitive resistance element **5** constitute a key speed detecting circuit KS and a key pressure detecting circuit KP, respectively. These circuits are connected to tone keyers S_a and S_b for controllably gating the tone signal. The actual circuit construction of the keyers will be explained in detail hereinlater with respect to an other embodiments. The tone signal is entered at a common input terminal T_i of the keyers and then is derived at a common output terminal T_o as an output signal having various electrical characteristics in response to the speed of the key being depressed which is detected by the coil **6** and to the pressure applied onto the same key detected by the element **5**. The terminal T_i at the input side of the keyers S_a and S_b is connected to a tone generator circuit (not shown). The key speed detecting circuit KS, the key pressure detecting circuit KP and the keyers S_a and S_b respectively correspond in number to the number of tone generator circuits provided in association with the playing keys in the electronic musical instrument.

In operation, in the state of the instrument where the key **1** is about to be depressed, there is produced no change in the flux in the coil **6** and, accordingly, the actuator is rendered inoperative, retaining the closed state of the normally closed contact (not shown) of the key switch. However, as the key **1** is depressed from the aforesaid inoperative position, the magnet **4** secured to the lever **1***c* of this key **1** is forced to move downwardly, and approaches, with certain speed, the coil **6** located thereunder. Along with this, the shouldered portion **1***a* of the key **1** is brought into contact with the pressure-sensitive resistance element **5**, and accordingly the sides of the magnet **4** are positioned to face the coil **6**. As the magnet **4** approaches the coil **6** at a given speed, the already established interlinking fluxes around the coil **6** are caused to vary to produce an electromotive force therein. The electromotive force thus generated is then introduced into the tone keyer S_a as shown in FIG. **2** and this electromotive force is used to key the keyer to control the tone signal generated in the tone generator (not shown). In other words, when the key **1** is depressed strongly or with a substantially great speed, the magnet **4** also travels at a high speed toward the coil **6**, and, as a consequence, the electromotive force generated in the coil **6** will have a greater magnitude. In contrast to this, when the key **1** is softly depressed or with a smaller speed to travel closer to the coil **6**, the electromotive force generated in the coil **6** will have a much smaller magnitude. The keyer which keys or gates the tone signal generated from the tone generator into the terminal T_o may be triggered so that the keyed output level at the terminal T_o may be controlled in accordance with the magnitude of the generated electromotive force. Furthermore, the keyer circuit S_a may be provided with a storing circuit for storing therein the electromotive force generated in the coil upon key depression, whereby the output of the keyer circuit may be maintained at the same keyed level for the period in which the key is being depressed.

On the other hand, during the stay of the key at the lowermost end of its stroke, if this key is depressed further to apply a pressure onto the upper face of the pressure-sensitive resistance element **5** at the pressing portion **1***a*, the resistance value of the element **5** decreases in accordance with the increasing amount of the applied pressure. As a consequence, the variation in the resistance value of the element **5** may be utilized to establish the amount of the electrical control of the keyer, e.g., the controlling voltage signal. The control signal thus established based on the variation in the resistance value of the pressure-sensitive element **5** is applied to the keyer circuit S_b of FIG. **2**, so that the level of the tone signal generated by the tone generator may be varied corresponding to said applied pressure to the element **5**. Thus, there is derived at the terminal T_o through both the keyers S_a and S_b, a keyed tone signal such that the tone signal whose amplitude is variable with the speed of the key depression and the tone signal whose envelope is variable in accordance with the magnitude of the pressing force applied onto the key during its stay at the lowermost end of its stroke are mixed together. Thus, this arrangement not only provides the advantage that the build-up envelope (amplitude) characteristic of the keyed tone signal can be varied in accordance with the normal depression of the key, i.e., the speed of the key depression — so-called a "touch-responsive control effect" —, but also it provides the so-called "after-control" effect as well.

Upon release of the depressed key **1**, however, it returns to the normal position by means of the spring **3**, and renders the keyer non-operative.

In FIG. **3**, there is shown a modification of a keyboard assembly shown in FIG. **1**, in which a flexible member **8** having a flexible arm capable of making a deflecting movement is securely provided on the frame **2**, on which a strain gauge **9** constituting a pressure-sensitive element is mounted so that the gauge **9** may change its electrical resistance in response with the amount of the deflection produced by said fluxible member **8** as a result of the pressure applied thereto by the shouldered portion **1***a* of the key **1** being depressed. This modification of the pressure-sensitive member, i.e., the second control means, provides the same effects of the two types as those described in connection with the arrangement in FIG. **1**.

As a substitution of the pressure-sensitive resistance element, there may be used an arrangement comprising a magneto-sensitive element such as a magneto-sensitive semiconductor device mounted on the frame **2** and a magnet secured to the key **1** so as to face the semiconductor device. A piezoelectric element may be utilized instead. The first control signal generating means comprising the magnet **4** and the coil **6** also may be substituted by a combination of a magneto-sensitive element and a magnet, or by a key switch having, in combination, a fixed contact and a movable contact. It should be understood also that, in FIG. **2**, tone signals which are different from each other may be supplied separately to the keyers S_a and S_b.

In FIG. **4**, there is shown another modification of the second control signal generating means provided in the keyboard assembly, in which a flexible member **15**, the pressure-sensitive resistance element **5** such as a strain gauge, a lower limit stopper **18** are arranged substantially in the reverse relation with the arrangement shown in FIG. **3**. That is, on the bottom surface of the key **1**, there is formed a recess **1***d* allowing deflection of the flexible member **15** spaced therefrom. The strain gauge **5** is mounted on this flexible member **15**. The stopper **18** is positioned on the frame **2** in such a way that it may be brought into contact with the flexible member **15** to produce a deflection of this flexible member **15**.

FIG. **5** shows a further embodiment of the keyboard assembly associated with a keying system. The embodiment features that actuation of both the first and second control signal generating means is effected by a single lever **4** having a magnet **4** at its end. Instead of the arrangement of the second control signal generating means shown in FIGS. **1**, **3** and **4**, a pressure-sensitive resistance element **17** — such as an electro-conductive rubber, a pressure-sensitive diode on the like **1** is positioned on the central bottom of a hollow bobbin having a coil **6** wounded therearound. The magnet **4** is adapted to be brought into contact with the element **17** by a further depres-

sion of the key 1 to apply a pressure onto this element 17 during the stay of the key at the lowermost end of its stroke.

Referring now to FIGS. 6*a* through 6*e*, a still further embodiment of the present invention is described, in which in FIG. 6*a*, KS_1 and KP represent a key contact circuit and a key pressure detecting circuit, respectively, which will be described later. These circuits KS_1 and KP are assigned for the control of a tone signal keyer circuit SW in such a way that the tone signal applied to the terminal T_1 can be controlled in its level in accordance with the key depression and that a resulting keyed tone signal having a variety of envelope (amplitude) characteristics may be derived at the output terminal T_o of the keyer circuit.

In FIG. 6*b*, there is shown a circuit diagram showing the details of the blocks shown in FIG. 6*a*, in which S represents generally a switch having a movable contact S_1 and a stationary contact S_2, and is adapted to close the movable contact S_1 upon depression of any one key K arranged on a keyboard of an electronic musical instrument. The movable contact S_1 is connected, through a resistor R_1, with a field-effect transistor Q (hereinafter referred to simply as an FET) at the gate of the latter, which the stationary contact S_2 is connected, via a pressure-sensitive variable resistor R_z, with a power source $+Vcc$. This variable resistor R_z has a resistance characteristic to vary its resistance value in response to the pressing force applied to the key K in such a way as shown in FIG. 6*d*. The juncture *d* between the switch S and the resistor R_1 is grounded through parallel-connected capacitor C and resistor R_2.

The source of FET Q is connected through a resistor R_3 to a juncture *e* which lies between two bleeder resistors R_4 and R_5 disposed in series between the power source $+Vcc$ and the ground, and has a signal input terminal T_1. The point *e* is grounded via a capacitor C_1. The drain of the FET Q is connected via a resistor R_6 to the source $+Vcc$, and has a signal output terminal T_o.

To the input terminal T_1 is applied a tone signal having a predetermined waveform from a known tone generator (not shown) such as a flip-flop type, while, at the output terminal T_o there can be derived a keyed tone signal of a predetermined level by varying the conductivity between the source and the drain of the FET Q so as to correspond to the variation of the gate potential of the FET Q which takes place depending upon the speed or amount of the key depressed. For the sake of simplicity, each block shown in FIG. 6*a* is enclosed by one-dot chain line.

The source voltage of the FET Q in the keyer is so set at a required level through the bleeder resistors R_4 and R_5 that the FET is rendered non-conductive showing an extreme increase in the drain-source impedance when the gate potential is equal to ground or zero voltage. The element R_z provided in the key pressure detecting circuit KP is so arranged that, as shown in FIG. 6*c*, it is adapted to be pressed upon by the shouldered portion *k* formed at a forward bottom portion of a key K which, in turn, is supported pivotably at a fulcrum 11 at its end, to apply a pressure onto the pressure-responsive element R_z which is provided at a corresponding position on a frame 12.

The numbers of each of the circuits KS_1, KP and SW which are housed in the console of the electronic musical instrument correspond in number, for example, 61, to the tone signal generators, respectively.

The operation of the above-mentioned embodiment will be described hereunder.

When any one of the keys K is manually depressed, the switch S is first closed to initiate the normal sounding of the tone at a level determined by the normal resistance value of the element R_z as on the conventional electronic musical instrument, and, thereafter, if the pressure-responsive resistive element R_z is pressed upon at its top surface by means of said surface *k* of the depressed key K when the key K stays at its lowermost end of stroke, the resistance of he element R_z will decrease in accordance with the amount of the pressure applied to the key as shown by the curve in FIG. 6*d*, and accordingly there will arise a change in the gate voltage of the FET Q in response to the amount of the pressure on the key, resulting in a variation in the source-drain impedance of the FET Q in compliance with the amount of the pressure applied onto the key. Thus, the input tone signal applied to the input terminal T_1 at the source side of the FET Q can be derived at the output terminal T_o at the drain side of the FET Q. Such a keyed tone signal is permitted to vary its envelope of the output level in many ways in response to the amount of the pressure of the key with respect to time *t* as shown in FIG. 6*e*. Therefore, during the stay of the key K at the lowermost end of its stroke, if this key is depressed further, the gate potential of the FET Q will increase, the level of the keyed tone signal will become higher. On the other hand, when the key K is softly depressed during the above-mentioned stay of the key, a keyed tone signal of a normal lower level, i.e., a tone signal level control based on "after-control," can be derived. Thus, there is obtained a special playing effect of the instrument.

Then, upon release of the depressed key K, it returns to the initial normal position by virtue of the resiliency of the spring 13, as shown in FIG. 6*c*. Along with this, the pressure applied onto the element R_z is released accordingly, and the resistance of the element R_z becomes higher again, and then the switch S becomes open. As a result, the gate potential of the FET Q is rendered zero, resulting in the shutting off of the input tone signal applied to the terminal T_z, and an output tone signal can no longer be detected.

Though the pressure-responsive variable resistive element whose resistance is decreased in accordance with a pressure applied thereto has been illustrated in this embodiment, the use of an element of the type in which its resistance is increased in accordance with the applied pressure, is of course possible. In which case, the wiring connection as shown in FIG. 6*b*, the element R_z and the resistance element R_4 must be replaced by each other. Further, the switch S can be omitted in the wiring of FIG. 6*b* if the element R_z used is of the type that its resistance value shows infinity or nearly zero when no pressure is applied.

In FIGS. 7*a* through 7*c* there is shown a modification of the embodiment shown in FIGS. 6*a* through 6*e*. In this modified embodiment, the key contact circuit KS_1 and the key pressure detecting circuit KP are connected to the keyers S_a and S_b having separate input terminals T_{11} and T_{12}, respectively, and the respective outputs of the keyers are connected in common with each other to have a common output terminal T_{10}. An example of a circuit diagram showing the details of the above-mentioned block circuits is illustrated in FIG. 7*b*. However, detailed description of the circuit arrangement is omitted for the sake of simplicity. According to this modified embodiment, when one key K is depressed, its associated switches S_{11} and S_{12} are closed. Whereupon, a positive voltage which is produced at a divider circuit composed of resistors R_{11} and R_{12} is applied, via a resistor R_{13}, to a first FET Q_{11} at its gate, so that the FET Q_{11} is rendered conductive, and a first tone input signal applied to the terminal T_{11} which is connected with the source of the FET Q_{11} is derived at the terminal T_o. The first tone output signal can be continuously obtained in its predetermined level, depicting a curve A shown in FIG. 7*c* and independently of the speed of the key depression during the stroke of the key. On the other hand, when the switch S_{12} is closed and when a pressure-responsive variable resistance element R_z which constitutes a key-pressure detecting circuit KP is given a desired resistance value, by a further pressing action of the key during its stay at the lowermost end of stroke, the gate voltage at an FET Q_{12} is altered to form a source-drain path of the FET Q_{12}, so that a second tone input signal applied to the input terminal T_{12} can be derived at the terminal T_{10} connected to the drain of the FET Q_{12}. Accordingly, it will be understood that separate keyed tone signals developed individually from the FET's Q_{11} and Q_{12} are mixed together and developed at the terminal T_{10}. A waveform of this mixed signal is shown in FIG. 7*c* by way of example, of which curve B indicates variation in the envelope or the level of a tone signal

keyed through the FET Q_{12}. This means that the envelope of the keyed signal may be varied with respect to time by a key pressing force at the lowermost end of the key stroke as described above. Thus, the so-called "after-control" is obtained also from this arrangement.

Referring to FIGS. 8*a* through 8*e*, there is shown an embodiment of the present invention, in which — in a keyer circuit SC capable of providing a percussive signal or an attack signal having a predetermined amplitude — there is additionally provided a keyer control circuit for causing the decay time of said signal to be varied in accordance with the pressure applied to a pressure-sensitive resistance varying element R_z by further pressing of the key at its normal lowermost end of stroke. The keying system associated with each key schematically comprises a controlling power source circuit DC, a key pressure detecting circuit KP having the element R_z, a key contact circuit KS_1 and the tone keyer circuit SC having a keying FET Q.

In a keyboard assembly as shown in FIG. 8*b*, a key K is pivotably supported at its one end on a fulcrum **21**, and a frame **22** adapted to be subjected to a pressure of a shouldered portion k formed in the forward bottom portion of the key K is provided with a leaf spring **24** arranged in parallel with the frame **22** via a resilient spacer **23** formed with felt or rubber and provided at the position facing said shouldered portion *k*. On one end of the leaf spring **24**, there is provided the above-mentioned pressure-sensitive resistance varying element R_z which may be either a conductive rubber, a strain gauge or a pressure-sensitive diode, in such a manner as is supported at its top by a support member or frame **25**. Accordingly, when the key K is depressed against a resilient force of a restoring spring **26** which is provided between the rear ends of the key K and the frame **25**, the shouldered portion *k* of the key K depresses the resilient spacer **23**, so that the depressing force exerted by the leaf spring **24** onto the element R_z substantially absorbed by the resilient spacer **23** and accordingly the resistance value of this element is increased in accordance with key pressure as shown in FIG. 8*c*, thus functioning as a key pressure detecting circuit KP. In the circuit of FIG. 8*a*, it will be noted that as the voltage changed on a capacitor C_{22} is applied through a resistor R_{23} to the gate of an FET Q, its drain-source impedance decreases in accordance with its input gate voltage level (as shown by a solid curve in FIG. 8*d*), and an input tone signal applied to an input terminal T_{21} of the keyer circuit can be derived at its output terminal T_{20} through the FET Q. At that time, if the key is faintly depressed to establish a smaller resistance in the element R_z, the positive voltage on the charged capacitor C_{22} is abruptly discharged as shown by a solid curve in FIG. 8*d*, and as a result, the envelope of the output signal at the output terminal T_{20} becomes as shown by the curve A in FIG. 8*e*, thus providing an attack signal or a percussive signal at the output terminal T_{20}. On the other hand, during the stay of the key K at its lowermost end of stroke, even if the key is strongly depressed further, this pressing force to the element R_z is reduced due to the resiliency of the resilient spacer **23**, so that the resistance value of the element R_z becomes greater as shown in FIG. 8*c*. As a result, the charge voltage of the capacitor C_{22} cannot be discharged abruptly so that the gate of the FET Q is held at a positive voltage. Accordingly, an input tone signal which is applied to the terminal T_{21} can be varied as desired during the attenuation of its envelope in accordance with the magnitude of the depression of key in such a way as indicated by the chain line B, the broken line C or the dotted curve D in FIG. 8*e*.

Referring to FIGS. 9*a* through 9*f*, there is shown another embodiment of the present keying system, in which a keyer circuit for providing a decay tone signal having a predetermined build-up amplitude in dependently of the speed of key depression, there is additionally provided a keyer control circuit capable of causing the envelope of the keyed tone signal to be varied continuously from the time the key is positioned at its lowest level, in accordance with the pressure applied to a pressure-sensitive resistance varying circuit after the normal key depression.

FIG. 9*a* shows a schematic diagram of this embodiment, in which PC and KP represent an attack pulse generator circuit and a key pressure detecting circuit having the resistance varying element R_{40z}, respectively, whereby keyer circuits S_a and S_b having keying FET's Q_{41}, Q_{42} and common input and output terminals T_{41}, T_{40}, respectively, are individually controlled to key the input tone signals and to develop the keyed signals with a variety of envelopes in accordance with the amounts of key depression. The circuit arrangement is substantially similar to that of FIG. 8*a* except these double keyers.

In operation, when the key is normally depressed to close a switch S, a DC voltage having a predetermined level as shown by a rectangular waveform in FIG. 9*c* is developed across a resistor **44** by dividing a DC power source voltage +E through bleeder resistors R_{41} and R_{42}. The developed voltage is differentiated by a circuit composed of a capacitor C_{40} and a resistor **45** into positive and negative-going pulses as shown in FIG. 9*d*. Through a diode D_{40}, only the positive-going pulse is derived and converted — through a capacitor C_{41} and a resistor R_{46} — to such a pulse voltage as shown in FIG. 9*e*. The pulse thus formed is applied to the gate of an FET Q_{41} to render it conductive in accordance with the applied pulse, so that an input signal applied to an input terminal T_{41} may be derived at an output terminal T_{40} in the form of an attack signal as shown by the curve A in FIG. 9*f*.

After the normal key depression if the key depressed at the lowermost end of its stroke is depressed further to press on the pressure-sensitive resistance varying element R_{40z}, the element varies its resistance value in accordance with the pressure applied thereto, so that the input tone signal applied to the other keyer FET Q_{42} is keyed to develop an output signal having a varying envelope or amplitude with respect to time as shown by the curve B in FIG. 9*f*.

FIGS. 10*a* and 10*b* show a modification of the embodiment illustrated in FIGS. 9*a* through 9*f*, in which the two keyer circuits S_a and S_b have input terminals T_{61} and T_{62}, respectively, and a common output terminal T_{40} so as to provide complicated tonal effects using different tone sources, for example, a trill playing.

Referring to FIGS. 11*a* through 11*d*, there is shown an embodiment of the keying system of the invention, in which in at least one keyer circuit for providing a varying envelope of a keyed signal in response to the speed of normal key depression, i.e., the so-called "touch-responsive control effect," there is additionally provided another keyer control circuit capable of varying the envelope of the keyed tone signal in accordance with the pressure applied to a pressure-sensitive resistance varying circuit after the normal key depression, thus providing the so-called "after-control effect."

FIG. 11*a* shows a schematic diagram of another embodiment of the keying system according to the present invention which comprises a key depressing speed detecting circuit KS which is responsive to the speed of depression of the corresponding key for generating an electromotive force and a key pressure detecting circuit KP responsive to the magnitude of the pressure applied by a key to the corresponding pressure-sensitive resistance varying element R_{80z} after the normal key depression to vary the resistance value of said element, whereby the tone keyers S_a and S_b are controlled so that input tone signals applied to a common input terminal T_{81} may be keyed and derived at a common output terminal T_{80} in the form of keyed signals having a variety of envelopes in accordance with both the key depressing speed and the key pressure.

FIG. 11*b* illustrates an example embodying the circuit diagram of the blocks shown in FIG. 11*a*, in which the two keyer circuits S_a and S_b have an FET Q_{81} and an FET Q_{82}, respectively, each of the transistors essentially effecting the keying or gating of an input signal.

FIG. 11*c* shows a modification of a keyboard assembly, which is similar to that of FIG. 6*c* except that a magnet M is mounted on a shouldered portion **93** of a key K and a coil L is mounted on a frame **92** in an opposing relation with the side of said magnet M.

In this circuit arrangement, it will be seen that a tone signal keyed at the FET Q_{82} may be varied with respect to time in its envelope of the output signal in accordance with the key pressure applied to the element R_{80z} as shown by the curve *p* in FIG. 11*d*.

Though this embodiment illustrates one common input terminal T_{81} for the keyer circuits S_a and S_b, each of the keyer circuits may be an individual input terminal so as to receive different tone signals independently of each other. That is, the latter is permitted to additionally control a tone having a different footage as illustrated in FIG. 11*e* as compared with the envelope produced by the arrangement of FIG. 11*a* as shown in FIG. 11*d*.

Referring to FIGS. 12*a* through 12*c*, there is shown still another embodiment similar to that of FIG. 8, in which the key contact detecting circuit of FIG. 8 is replaced by a touch-responsive control circuit, i.e., a key depressing speed detecting circuit KS responsive to the speed of key depression to generate an electromotive force adapted for triggering at least one keyer circuit. This arrangement features that in a keyer circuit for providing a percussive signal or an attack signal whose build-up amplitude is varied in accordance with the speed of key depression, there is provided a keyer control circuit which is capable of varying a decay time of either of said signals in accordance with the magnitude of key pressure applied after the normal key depression.

In the arrangement shown in FIG. 12*a*, when the key K is quickly depressed and, thereafter, when it is strongly pressed upon at its lowermost end of stroke, the envelope of the keyed output tone signal becomes as shown by the two-dot chain line in FIG. 12*b*. When the further pressure force applied onto the key at its lowermost level of stroke — following the normal speed depression of the same — is varied in many ways, there are obtained various kinds of envelopes having different lengths of decay time in the manner as shown by other chain curves in FIG. 12*b*. Furthermore, in case the normal depression speed of the key and the pressure force applied to the key at its lowermost level of stroke are both small, the resulting envelope of the keyed output signal will be small in amplitude and short in decay time as shown in FIG. 12*c*.

FIGS. 13*a* through 13*c* show a modification of FIG. 9, in which a detected signal from the key depressing speed detecting circuit KS is applied to a damped pulse shaping circuit to provide a damped pulse whose amplitude is in response to the depressing speed of the key, whereby the so-called "touch-responsive, percussive control effects" are obtained.

FIG. 13*a* shows an essential portion of the modification.

Though the modification of FIG. 13*a* illustrates one common input terminal connected to both the keyer circuits S_a and S_b, it is needless to say that they may have individual input terminals separately from each other.

What is claimed is:

1. In an electronic musical instrument having playing keys for manual depression to a stop position, a keying system for gating tone signals, comprising:

at least one keyer provided for each key in associated relation therewith,

first control means associated with said key for actuating said keyer during the depressing stroke of said key before said key reaches said stop position, and

second control means associated with said key for controlling such keyer in response to the depressing force applied to said key during its stay at said stop position.

2. The keying system according to claim 1, in which said second control means includes a pressure-sensitive resistance element capable of varying an electrical property thereof in response to the magnitude of the pressure applied thereto.

3. The keying system according to claim 2, in which said pressure-sensitive resistance element includes a strain gauge provided on one end of a flexible member provided in either one of a manually movable portion and a fixed portion of a keyboard assembly, said strain gauge being adapted to be subjected to a pressure by a further pressing of the key beyond normal key depression.

4. The keying system according to claim 2, in which said pressure-sensitive resistance means has a piezo-electric member.

5. The keying system according to claim 1, in which said first control means includes means for generating an electromotive force in response to the speed of the key depression.

6. The keying system according to claim 5, in which said electromotive force generating means includes a magnet mounted on the key and a coil assembly disposed on a fixed member, said magnet being adapted to be untouchably surrounded by said coil assembly so as to face each other.

7. The keying system according to claim 6, in which a pressure-sensitive resistance element is housed within the coil assembly, said element facing said magnet and is adapted to be subjected to a pressure by the face of the magnet via a corresponding key when the latter is pressed beyond the normal key depression.

8. The keying system according to claim 7, in which said pressure-sensitive resistance element may be one of a piezo-electric element and a magneto-sensitive element.

9. The keying system according to claim 1, in which said first means is constituted by a key contact circuit for effecting a switching action to the keyer circuit to key an input tone signal at a predetermined level, and said second control means is constituted by a pressure-sensitive resistance varying circuit for varying the resistance value in accordance with a pressure applied thereto to thereby control an amplitude or envelope of the keyed tone signal.

10. The keying system according to claim 9, in which said key contact circuit and said pressure sensitive resistance varying circuit are connected to respective keyer circuits each of whose input is an individual tone signal and whose outputs has a common output terminal.

11. The keying system according to claim 1, in which said first control means functions to provide a percussive envelope of the keyed tone signal and said second control means functions to vary a decay time of said envelope.

12. The keying system according to claim 1, in which said first control means includes an attack pulse generator connected to a first keyer circuit for generating an attack tone signal from the keyer with a predetermined buildup and decay envelope, and said second control means includes a pressure-sensitive resistance varying circuit varying the resistance value of a resistive element in accordance with a pressure applied thereto and connected to a second keyer circuit, said resistance varying circuit varying the envelope of a tone signal keyed by said second keyer.

13. The keying system according to claim 12, in which said first and second keyers have a common input terminal and a common output terminal.

14. The keying system according to claim 12, in which said first and second keyers have respective input terminals separate from each other.

15. The keying system according to claim 1, in which said first control means includes a key speed detecting circuit connected to a first keyer circuit and capable of generating an electrical signal in response to the speed of key depression, and second control means includes a pressure-sensitive resistance varying circuit connected to a second keyer circuit and capable of varying the resistance value of a resistive element in accordance with a pressure applied thereto by a key pressing action to thereby vary the envelope of a tone signal keyed by the second keyer circuit.

16. The keying system according to claim 15, in which said first and second keyers have a common input terminal and a common output terminal.

17. The keying system according to claim 15, in which said first and second keyers have respective input terminals separate from each other.

18. The keying system according to claim 1, in which said first control means functions to provide a percussive envelope of the keyed tone signal having an amplitude in response to the depression speed of the key, and said second control means functions to vary a decay time of said envelope.

19. The keying system according to claim 1, in which said first control means includes an attack pulse generator connected to a first keyer circuit for generating an attack tone signal from the keyer with an amplitude in response to the depression speed of the key; and said second control means includes a pressure-sensitive resistance varying circuit varying the resistance value of a resistive element in accordance with a pressure applied thereto and connected to a second keyer circuit, said resistance varying circuit varying the envelope of a tone signal keyed by said second keyer.

20. The keying system according to claim 19, in which said first and second keyers have a common input terminal and a common output terminal.

21. The keying system according to claim 19, in which said first and second keyers have respective input terminals separate from each other.

22. The keying system according to claim 19, in which a pulse shaping circuit is provided between said attack pulse generator and said first keyer circuit.

* * * * *