United States Patent

Hirano

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[54] SUSTAIN KEYER CIRCUITRY WITH SUSTAIN TIME CONTROL CIRCUIT IN ELECTRONIC MUSICAL INSTRUMENT

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[21] Appl. No.: **27,027**

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Apr. 14, 1969	Japan	44/28924

[52] **U.S. Cl.** **84/1.13,** 84/DIG. 23

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

[58] **Field of Search** ..... 84/1.01, 1.13, 1.26 D, 1.26 E, 84/1.26 O; 307/246, 264, 268, 304, 251

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Primary Examiner—Thomas J. Kozma
Assistant Examiner—Stanley J. Witkowski
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[57] **ABSTRACT**

A sustain keyer circuitry in electronic musical instrument having two field effect transistors connected in series to each other, the source electrode of the first FET being grounded and the gate electrode thereof being adapted to receive tone signals, the drain electrode thereof being connected to the source electrode of the second FET whose drain electrode is connected to the power source via a load resistor, the gate electrode of said second FET being connected to keying means having a key-operated switch and capable of keying the control voltage to be applied to the gate electrode of said second FET, so that, by the keying operation of said key-operated switch, said tone signal is derived across the load resistor, said circuitry being arranged so that the on-off ratio, i.e., the conducting to nonconducting level ratio of the tone signal, is increased substantially whereas, accordingly, the load in a tone generator is reduced. By incorporating, in said sustain keyer circuitry, a sustain time control circuit, i.e., an envelope-forming circuit, which is formed by the use, in a charging and discharging circuit which is employed as the time constant circuit for determining the sustain time of said electronic musical instrument, of a capacitor of a relatively low capacitance and a third FET having an extremely high inner impedance and being used as a variable resistance element, said circuitry can be easily integrated.

13 Claims, 15 Drawing Figures

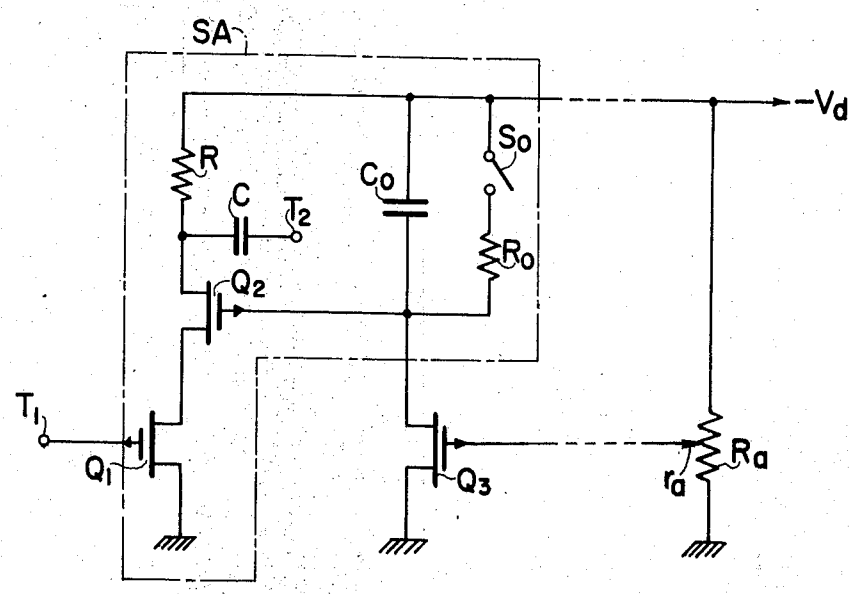


FIG. 1
PRIOR ART

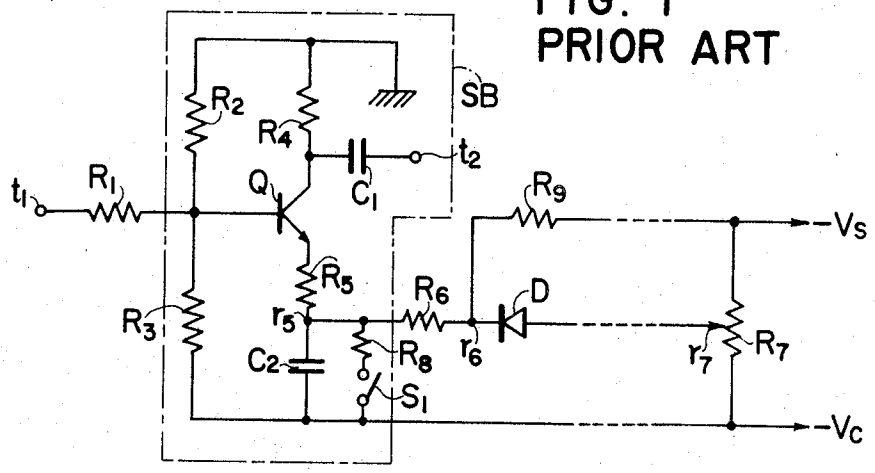
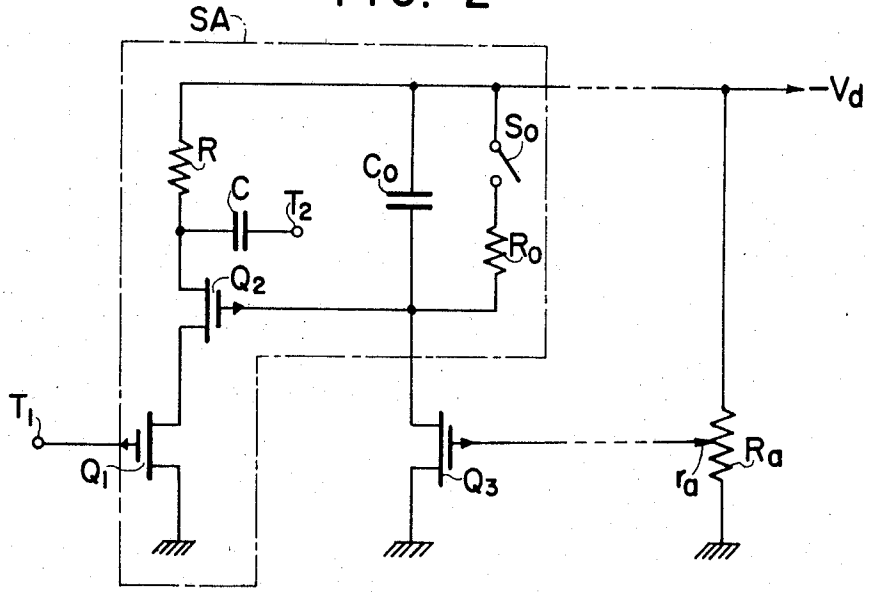


FIG. 2



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FIG. 3

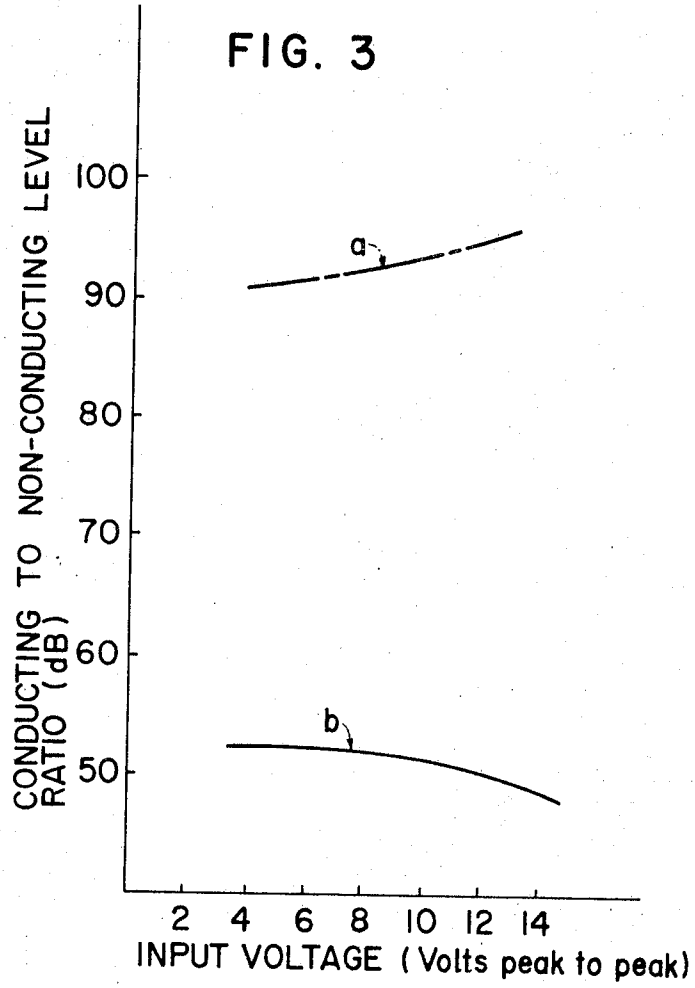
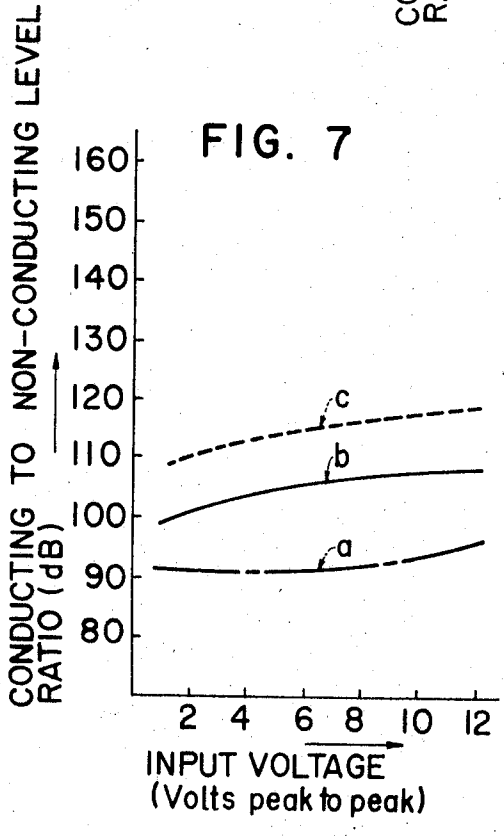


FIG. 7



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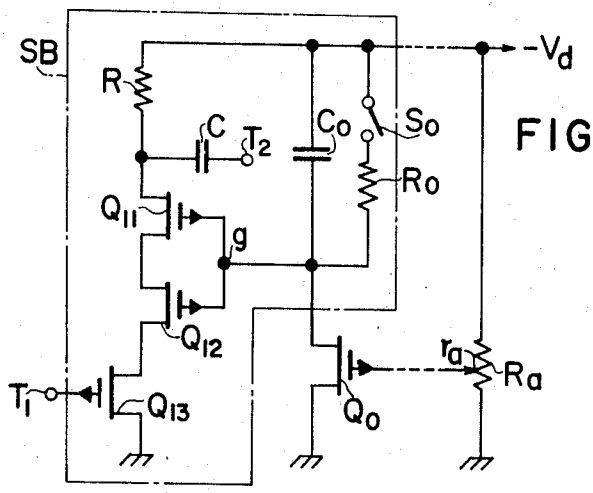


FIG. 4

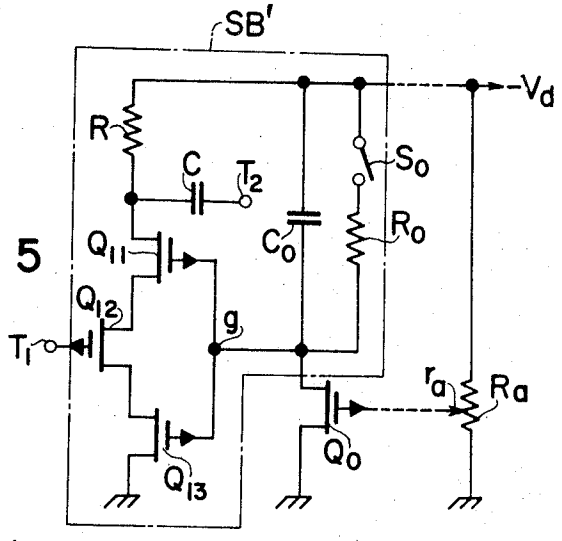


FIG. 5

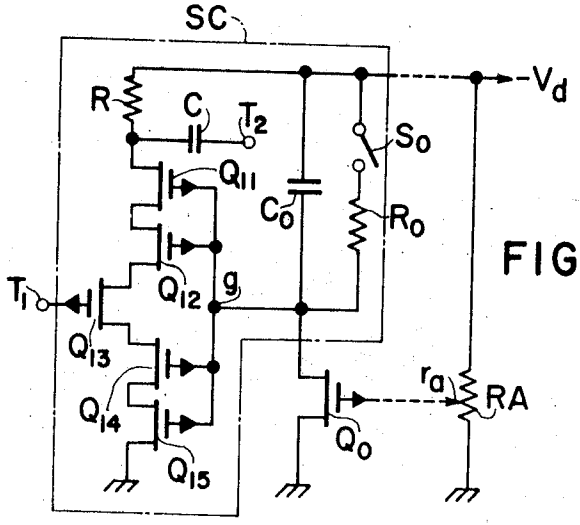


FIG. 6

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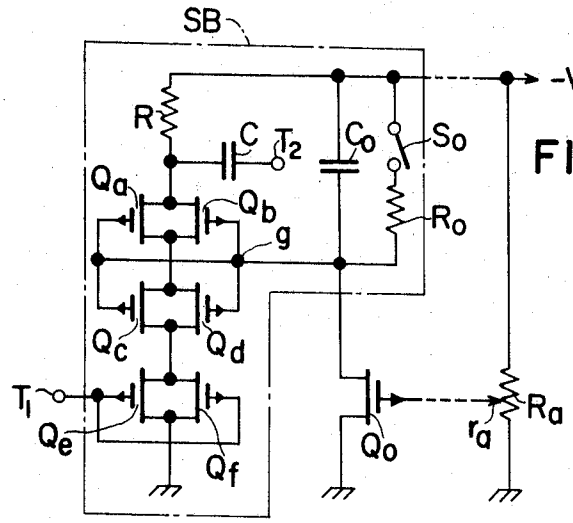


FIG. 8

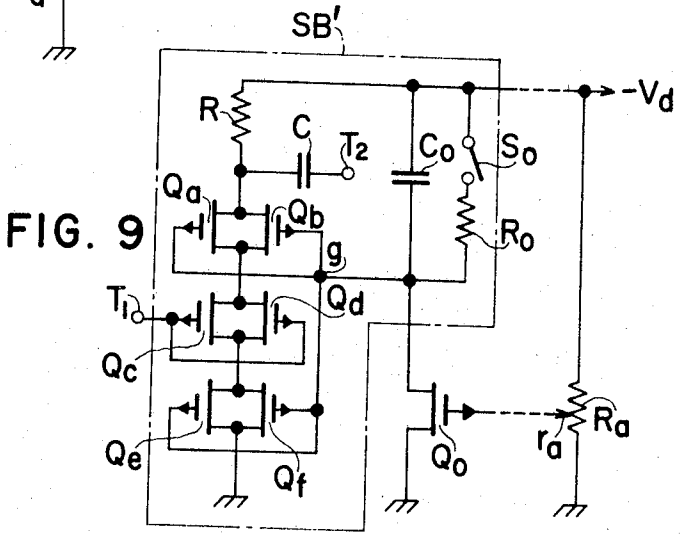


FIG. 9

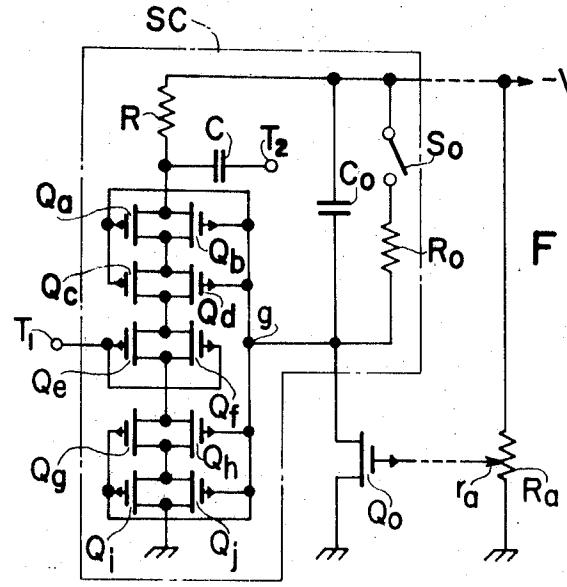


FIG. 10

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FIG. 11

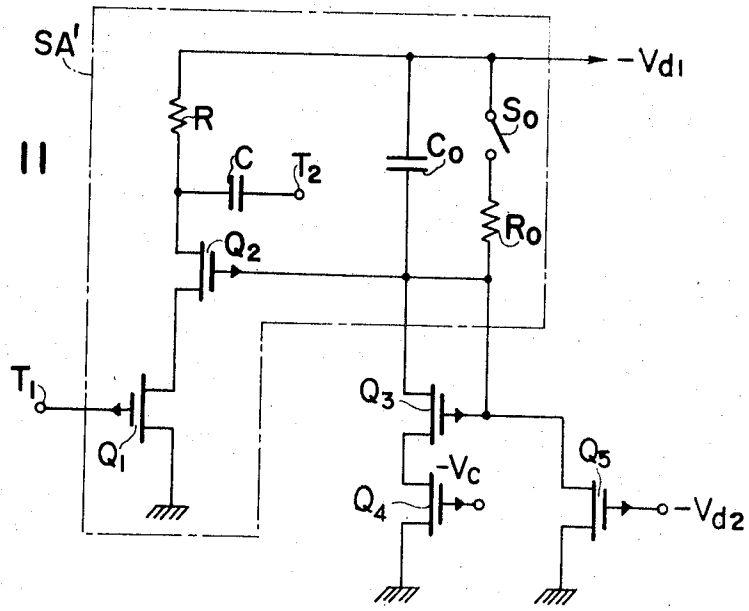


FIG. 12

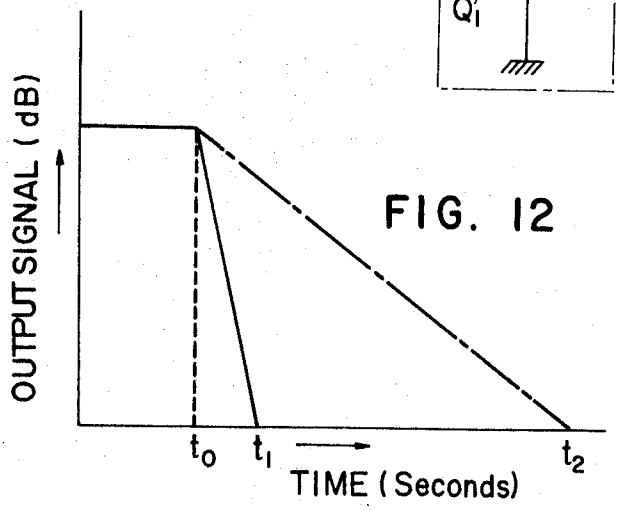
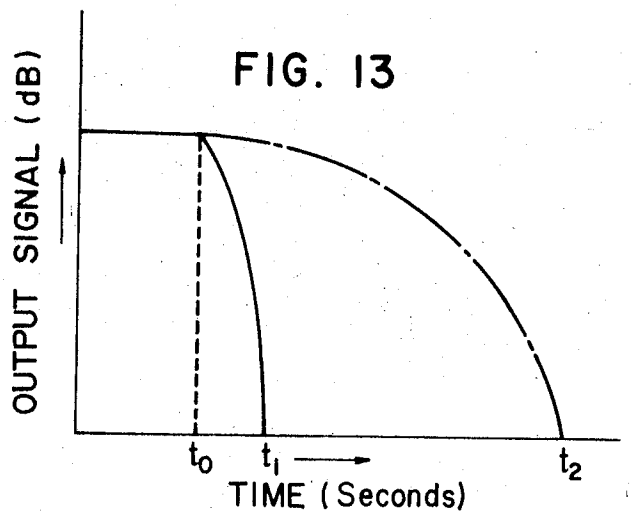


FIG. 13



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FIG. 14

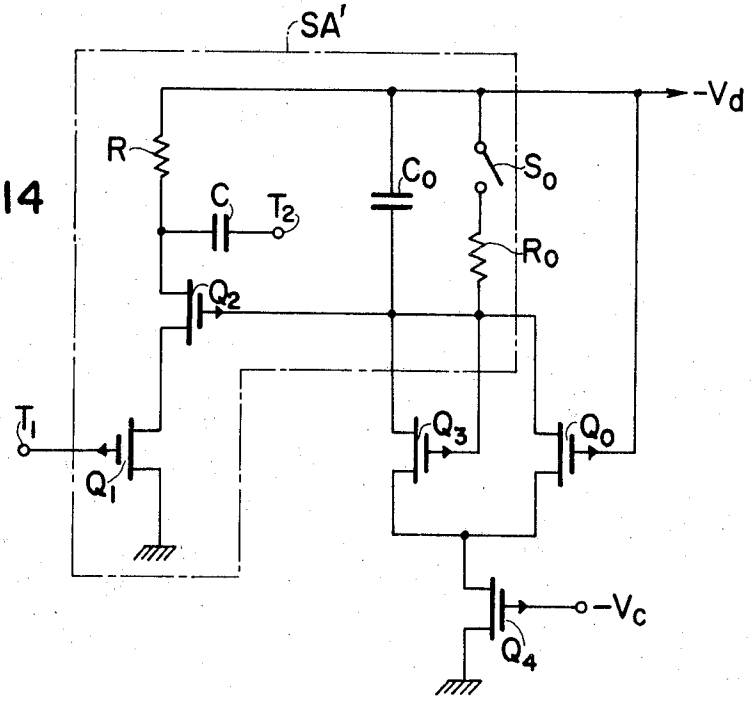
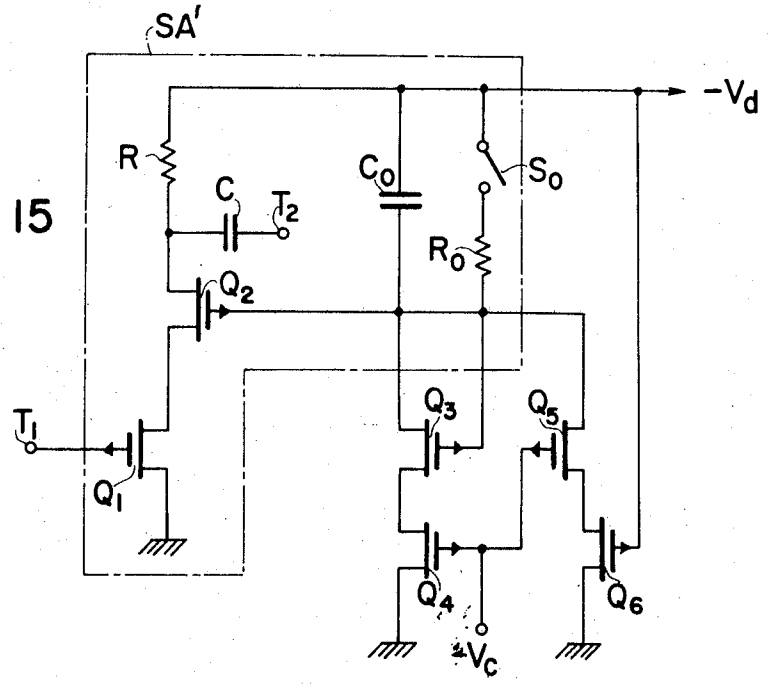


FIG. 15



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SUSTAIN KEYER CIRCUITRY WITH SUSTAIN TIME CONTROL CIRCUIT IN ELECTRONIC MUSICAL INSTRUMENT

This application is related to U.S. application Ser. No. 27,028 filed on Apr. 9, 1970, which related application represents an improvement over the subject matter of this application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is concerned with a sustain keyer circuitry for use in an electronic musical instrument, and more particularly, it relates to a sustain keyer circuitry provided with a sustain time control circuit and being capable of integrating the circuitry in the electronic musical instrument.

2. Description of the Prior Art

Referring to FIG. 1, there is shown a conventional sustain keyer circuitry for use in an electronic musical instrument, which is arranged in such a way that an input terminal t_1 to which a tone signal of a low frequency derived from a tone generator (not shown) which is comprised of, for example, a flip-flop circuit is applied is connected, via a resistor R_1, to the base electrode of a transistor Q, said base electrode being connected, via biasing resistors R_2 and R_3, respectively, to both the ground and the power source $-V_c$, the collector electrode of said transistor Q being connected, via a resistor R_4 and a capacitor C_1, respectively, to both the ground and a signal output terminal t_1, the emitter electrode of said transistor Q being connected, via a series circuit consisting of a resistor R_5 and a capacitor C_2, to the power source $-V_c$, the junction r_5 of the resistor R_5 and the capacitor C_2 being connected, via a series circuit consisting of a resistor R_6 and a diode D, to a slidable contact r_7 of a variable resistor (potentiometer) R_7 which, in turn, is interposed between the power sources $-V_s$ and $-V_c$, said juncture 5 being connected, via a series circuit consisting of a resistor R_8 and a key-operated switch S_1 which is adapted to be keyed in association with the depressing actions applied onto the keys of the keyboard of the electronic musical instrument, to the power source $-V_c$, the juncture r_6 between said diode D and said resistor R_6 being connected, via another resistor R_9, to the power source $-V_s$.

It is to be noted that the sustain keyer circuit SB which is located within the block defined by a-dot-and-a-dash line in FIG. 1 and which is comprised of such elements as the transistor Q, a resistor and a capacitor, and said input terminal t_1 are provided respectively in, for example, a console of an electronic musical instrument in a number corresponding to the number, for example, 90 to 100, of the tone generators installed in accordance with the number of the keys of the keyboard of the electronic musical instrument. Whereas, the variable resistor (potentiometer) R_7 is provided only one in number so that its slidable contact r_7 is connected in common to the number of said sustain keyer circuits SB corresponding in number to said keys, via the corresponding number of diodes, respectively.

In the known circuitry having the foregoing construction, the respective resistors R_1 to R_9 and the respective power sources $-V_s$ and $-V_c$ are arranged beforehand to have preset values in such a way that the transistor Q may be rendered to its "cutoff" state or to its "on" state by the keying operation performed by the player or the user of the instrument on the key-operated switch S_1 which is adapted to be keyed in association with the depression applied onto the selected keys of the keyboard of the electronic musical instrument, and along with this, the arrangement is provided to be operative so that, when this key-operated switch S_1 is closed, the transient characteristic in the course of the beginning of conduction of said transistor Q is determined by a time constant which, in turn, is determined by the capacitance of the capacitor C_2 connected to the emitter circuit of the transistor Q, the resistances of the resistors R_5 and R_8 and the inner resistance between the collector and the emitter electrodes in the conductive state of said transistor Q, to thereby determine the buildup characteristic of the signal detected at the output terminal t_2 on the collector side thereof, whereas, when the key-operated switch S_1 is opened, the transient characteristic of the transistor Q in its course of the ending of conduction is determined by the time constant which, in turn, is determined by the capacitor C_2, the resistances of the resistors R_6 and R_9, and the value of resistance between the slidable contact of the variable resistor (potentiometer) R_7 and the power source $-V_c$(or $-V_s$), to thereby obtain the decay characteristic (so-called sustain time) of the output signal derived from said output terminal t_2 in the form of a desired characteristic. Furthermore, in said known circuitry, arrangements are made to eliminate the possible leakage of a signal due to the reverse directional breakdown voltage between the base and emitter electrodes of the transistor Q, the input signal from the tone generator is divided in its voltage by the resistors R_1 and R_2, and by the resistor R_3 to drop the input voltage applied to the base electrode of said transistor Q below the base-emitter breakdown voltage, whereas, the input impedance of the sustain keyer circuit SB is elevated by such an element as the resistor R_1 up to the order of about 100 kiloohms to thereby reduce the loan on the tone generator.

Accordingly, in the circuitry of the prior art, it should be understood that, even when the key-operated switch S_1 is opened to cut off the transistor Q for shutting off the output signal which is detected at the collector side of the transistor Q, there may leak out, through the base and collector electrodes of the transistor Q, a tone signal of a considerably large amplitude which is always applied to the input terminal t_1 and such a leakage may be thus detected.

Accordingly, in the circuitry of the prior art, it should be noted that, even when the key-operated switch S_1 is opened to render the transistor Q to the "cutoff" state and to, thereby, shut off the output signal which is detected at the collector side of said transistor, the tone signal having a considerably large amplitude which is always applied to the input terminal t_1 may leak out—owing to the effect caused by such reasons as the static capacity between the base and collector electrodes of the transistor Q and the dark current (leakage current) which flows between the collector and emitter electrodes of the transistor—and may be detected at the output terminal t_2 side via the base and collector electrodes of the transistor Q. Accordingly, the level ratio of the output signal at the on-off time of the transistor Q (meaning the conducting to nonconducting level ratio of the output signal) due to the keying operation of the key-operated switch S_1 is obtained only in as low a level of the order as 50–55 db. as shown by the actually measured values which are indicated by the solid curve *b* in FIG. 3. Therefore, even when the keys of the keyboard of the electronic musical instrument are not depressed at all, there will come out, through the speaker or the like of the instrument, a noise which is very low in loudness but resembles the sound produced when all of the keys of, for example, an organ are depressed. Thus, this sound or noise will become a nuisance when the electronic musical instrument of this type is played. As described, the circuitry of the prior art not only will not permit one to obtain a conducting to nonconducting level ratio which is sufficient for an electronic musical instrument of a large scale having complicated circuitries, but also will make the integration of the circuitry of this type markedly difficult because of the fact that the sustain keyer circuit SB requires a number of resistors. Furthermore, even when an effort is made to lessen the load to be applied on the tone generator by, for example, connecting the resistor R_1 in series to the input side of the transistor Q in the manner as described previously, there will be obtained as small an input impedance as the order of only 100–200 KΩ at best, with the result that there may arise distorted output waveform depending on the type of the tone generator employed, so that the circuitry of the prior art had the serious drawback that the quality of the tone was poor and that there arose a great deal of loss in the output signal which was not economical.

Furthermore, especially in order to obtain a desired sustain effect in the known circuit arrangement by rendering the transistor Q to its "cutoff" state by opening the key-operated switch S_1 after the lapse of a predetermined sustain time, it has been necessary, on the one hand, to set the time constant—which is determined by such factors as the capacitance of the capacitor C_2, the resistance values of the resistors R_6 and R_9, and the resistance value between the slidable contact r_7 of the variable resistor R_7 and the power source $-V_c$(or $-V_s$)—so as to assume a considerably large value. Along with this, it has been necessary also, on the other hand, to use the aforesaid capacitor C_2 having a considerably large capacitance, or in other words, it has been necessary to use an electrolytic capacitor having a capacitance of, for example, the order of 100 microfarads, in view of the fact that there is a limit within a certain range in the selection of the values of the aforesaid respective resistors when the transistor Q is selected so as to display the optimum action with respect to the fixed power sources $-V_c$ and $-V_s$. This not only will lead to an increase in the size of the circuitry and an increase in the cost, but also to the following inconvenience. That is to say, since an electrolytic capacitor of this type having a large capacity presents a variance in the value of its static capacitance which is usually in such a large range as from −10 to +200 percent, this variance will directly result in the variance of the aforesaid time constant value. Accordingly, this variance of the time constant will lead to a variance of a large range of the transient characteristic, at the opening of the key-operated switch S_1, of the cutoff signal, which will constitute a great hindrance at the time the electronic musical instrument of this type is played. Also, in view of the necessity for the use of five resistors R_5 to R_9 which are required for the formation of the circuitry, there has been the serious drawback that the integration of the circuitries of this type becomes markedly difficult.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a sustain keyer circuit for use in an electronic musical instrument, which improves the conducting to nonconducting level ratio of the signal, by incorporating, in said circuit, two field effect transistors as the switching elements which are connected in series to each other.

Another object of the present invention is to provide a sustain keyer circuit for use in an electronic musical instrument, which improves the safety as well as the reliability of keying operation, and which is especially safe in case of a failure of the action of the instrument due to a short circuit of said transistors, by incorporating, in said circuit, two or more field effect transistors as the switching elements which are connected in series to each other.

Still another object of the present invention is to provide a sustain keyer circuit for use in an electronic musical instrument, which minimizes a wasteful loss of signal in addition to the aforesaid advantages especially the advantage represented by the safety in case of a failure of the action of the instrument due to a short circuit of said transistors, by incorporating, in said circuit, three or more serial sets of field effect transistors which, in each set, are connected in parallel to each other, said serial sets serving as the switching elements.

A further object of the present invention is to provide a sustain keyer circuit which is capable of producing a prolonged decay time by the use of a capacitor having a small capacitance.

Yet a further object of the present invention is to provide a sustain time control circuit utilizing a field effect transistor for use in an electronic musical instrument.

Still further object of the present invention is to provide a sustain time control circuit for use in an electronic musical instrument, which is of the arrangement that a serial and/or parallel circuit consisting of three field effect transistors is connected in series to a capacitor to form a charging and discharging circuit for use as the time constant circuit intended for determining the sustain time and which is operative so that a desired sustain time may be obtained by varying the DC gate potential of one of said three field effect transistors.

Another object of the present invention is to provide a sustain time control circuit for use in an electronic musical instrument, which permits one to control the sustain time as desired while keeping the envelope within the decay time of the tone signal, i.e., within the so-called sustain time, to assume an exponential damping curve, and which simplifies the circuit arrangement by reducing the number of the biasing power sources intended for the field effect transistors.

Still another object of the present invention is to provide a sustain time control circuit for use in an electronic musical instrument, in which a serial and/or parallel circuit consisting of four field effect transistors and being connected in series to a capacitor to form a charging and discharging circuit for determining the sustain time to be operative so that, by simultaneously altering the DC gate potential of each of said transistors in the same direction, a desired sustain time is obtained, while, on the other hand, reducing the number of biasing power sources.

Yet another object of the present invention is to provide the aforesaid circuitry which is comprised mainly of such transistors as are easily manufactured with semiconductor integrated circuits, while reducing the number of resistors which are difficult to make with semiconductor integrated circuits, so that said circuitry is suitable for being made with semiconductor integrated circuits.

The foregoing as well as the other objects, features and attendant advantages will be understood more clearly by reading the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram, showing an example of the conventional sustain keyer circuitry for use in an electronic musical instrument;

FIG. 2 is a circuit diagram, showing a sustain keyer circuitry provided with a sustain time control circuit and representing one embodiment of the invention;

FIG. 3 is a graph, illustrating the conducting to nonconducting level ratio of the circuitry of FIG. 2;

FIG. 4 is a circuit diagram of a sustain keyer circuitry according to another embodiment of the invention;

FIGS. 5 and 6 are circuit diagrams, showing modifications, respectively, of the circuitry of FIG. 4;

FIG. 7 is a graph, showing the conducting to nonconducting time ratio of the circuitries of FIGS. 4 to 6;

FIG. 8 is a circuit diagram of a sustain keyer circuitry according to still another embodiment of the invention;

FIGS. 9 and 10 are circuit diagrams, showing modifications, respectively, of the circuitry of FIG. 8;

FIG. 11 is a circuit diagram, showing a sustain time control circuit according to another embodiment of the present invention;

FIGS. 12 and 13 are diagrams, illustrating the functions of the circuitries shown in FIGS. 11 and 2, respectively;

FIG. 14 is a circuit diagram of a sustain time control circuit according to still another embodiment of the present invention; and

FIG. 15 is a circuit diagram of a sustain time control circuit according to yet another embodiment of the invention.

In the drawings, like parts are indicated by like symbols and reference numerals.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will hereunder be described in detail with respect to an embodiment shown in FIG. 2.

The circuit arrangement embodying the present invention is such, (as shown within the block indicated by a-dot-and-a-dash line in FIG. 2,) that there are used first and second field effect transistors, FET Q_1 and FET Q_2, which are connected in

series so as to be able to be operative from both DC and AC viewpoints, and the source electrode of the first FET Q_1 is grounded, whereas a tone signal is applied to the gate electrode thereof through an input terminal T_1, the drain electrode thereof being connected to the source electrode of the second FET Q_2 which is the other of the two, the drain electrode of this second FET Q_2 being connected to a power source $-V_d$ via a load resistance element R, there being interposed a serial circuit consisting of a resistance element R_o and a key-operated switch S_o between the gate electrode of said second FET Q_2 and said power source $-V_d$ to thereby form a sustain keyer circuit SA so as to derive said tone signal at the output terminal T_2 from the drain electrode of said second FET Q_2 through a capacitor C by the keying operation of said key-operated switch S_o. Furthermore, the gate electrode of said second FET Q_2 is connected to the power source $-V_d$ via a capacitor C_o. Also, this gate electrode of the second FET Q_2 is connected to the drain electrode of a third FET Q_3 having its source electrode grounded, and the gate electrode of this third FET Q_3 is connected to a slidable contact r_a of a variable resistor R_a which, in turn, is interposed between said power source $-V_d$ and the ground, to thereby form a sustain time control circuit. In FIG. 2, the symbols C_o and Q_3 represent a capacitor for determining the sustain time and another FET having its source electrode grounded and being used as a resistance element, respectively. Furthermore, the sustain keyer circuit SA given in the block indicated by a-dot-and-a-dash line and said FET Q_3 are provided for example, in a console of the electronic musical instrument each in a number, for example, of 90–100 which is the number of tone generators provided in accordance with the number of the keys of the keyboard of the electronic musical instrument. Whereas, there is used only one variable resistor (potentiometer) R_a which is assigned for determining the resistance value between the drain and source electrodes of the FET Q_3 by adjusting the gate potential of this FET Q_3, said variable resistor R_a being arranged so that its slidable contact r_a is used in common to the respective gate electrodes of the multiplicit number of FET Q_3. Whereby, by operating the aforesaid variable resistor R_a, the sustain time of the output signal at the opening of the key-operated switch S_o may be adjusted to a desired time via the FET Q_3.

The sustain keyer circuit of the present invention which contains therein the sustain time control circuit is of the foregoing arrangement. Description will hereunder be made on the actions of this circuitry. The player or the user of the electronic musical instrument may key the key-operated switch S_o which is adapted to close in association with the depression of the selected keys of the keyboard of this instrument performed by the player. The resistance elements R and R_o as well as the power source $-V_d$ are preliminarily arranged so that these resistance elements will have values and the power source will have a voltage value such that both the FET Q_1 and the FET Q_2 will be rendered to the "cutoff" state or to the "on" state upon said keying operation of the player. Also, arrangement is provided so that, when the key-operated switch S_o is closed, the transient characteristics in the course of the starting of conduction of both the FET Q_2 and FET Q_1 are to be determined by the time constant which, in turn, is determined by the capacitance of the capacitor C_o and the resistance element R_o which are interposed in the gate circuit of the FET Q_2 to thereby determine the buildup characteristic of the signal detected at the output terminal T_2. Whereas, when the key-operated switch S_o is opened, the transient characteristics in the course of the ending of conduction of both the FET Q_1 and the FET Q_2 are to be determined by the time constant which, in turn, is determined by such factors as the capacitance of the aforesaid capacitor C_o and the resistance value between the drain and source electrodes of the FET Q_3 to obtain a desired decay characteristic (meaning the so-called sustain time) of the aforesaid signal detected. Furthermore, a tone signal having a predetermined frequency and a predetermined waveform obtained from a separately installed tone generator (which includes flip-flop circuits, but any known devices will be usable, and therefore, it is not shown in the drawing) is always applied to the input terminal T_1. In case the FET Q_3 is rendered to its "on" state while retaining its predetermined inner resistance value by adjusting the position of the slidable contact r_a of the variable resistor R_a, it should be noted that, when the key-operated switch S_o is open, the juncture between the drain of the FET Q_3 and the gate of the FET Q_2 in each set, is at the ground potential. Therefore, there is applied to this gate of the FET Q_2 no negative voltage which would render the FET Q_2 to the "on" state, with the result that this FET Q_2 is in its "cutoff" state. Also, there is applied no negative voltage to the drain electrode of the FET Q_1 which is connected to the source electrode of said FET Q_2, and accordingly, this FET Q_1 is also in its "cutoff" state. After all, both of the two FET's, Q_1 and Q_2, which are connected in series to each other are retained in their shutoff state, so that the leakage current (dark current) between the drain electrode and the source electrode between these two FET's is minimal, being in the order of 10^{-9} ampere (1 nano-ampere). Also, the static capacity between the drain electrode and the source electrode between these two FET's is likewise markedly small as compared with that of the ordinary transistors. Besides, these two FET's are connected in series from both the AC and DC viewpoints, and accordingly, the aforesaid capacity is reduced to approximately one-half. Thus, the tone signal which is always applied to the gate side of the FET Q_1 will hardly be produced at the drain side of the FET Q_2. As a result, there can be obtained a conducting to nonconducting level ratio of the signal (or the signal to noise ratio) which is at least 90 db. as will be noted from the actually measured value as indicated by the dot-dash curve *a* in FIG. 3.

It is to be noted that, in the foregoing operation, the capacitor C_o which is connected to the gate circuit of the FET Q_2 is in the state of being charged up with the voltage of the power source $-V_d$ through the third FET Q_3 having a considerably high drain-source resistance.

On the other hand, when said key-operated switch S_o is closed, the charge on the capacitor C_o which has been in the charged-up state in the foregoing stage is discharged through the resistance element R_o which is connected in series to this key-operated switch S_o, and also, the potential of the juncture between the gate electrode of the FET Q_2 and the drain electrode of the FET Q_3 approaches the potential of the power source $-V_d$. As a result, first, the FET Q_2 will be rendered to the conductive state, and then almost simultaneously therewith the FET Q_1 will be rendered to the conductive state. Accordingly, the tone signal which is being applied to the gate electrode of this FET Q_1 is detected at the output terminal T_2 via the drain electrode of this first FET Q_1 and the source and drain electrodes of the second FET Q_2 successively in this order. This detected tone signal is then amplified, for example, and thus, it is possible for one to obtain an audible sound wave converted from said tone signal and given out through a loudspeaker or like appliances.

Next, when the key-operated switch S_o is opened again, the capacitor C_o which has been in the discharged state in the foregoing stage begins to be charged up with the voltage of the power source $-V_d$ via a considerably high predetermined inner resistance between the drain-source circuits of the FET Q_3. Also, the potential of the juncture between the gate of the FET Q_2 and the drain of the FET Q_3 approaches the ground potential. Along with this, when the potential of each of the plurality of juncture rises above (meaning more positive than) a predetermined potential, the FET Q_2 will be rendered to its nonconductive state before the other, and then, almost simultaneously with this, the FET Q_1 will also be rendered to its nonconductive state. Thus, both of the two FET's will be rendered to the nonconductive state as in the case of the opened state of the key-operated switch S_o. Accordingly, the tone signal which is being applied to the input terminal T_1 is substantially completely shut off by these FET's at the end of the lapse of a sustain time which is determined by a time con-

stant which, in turn, is determined by the capacitance of the capacitor C_o and the inner resistance of the FET Q_3. As a result, the signal ceases to be detected at the output terminal T_2. At such a time, the conducting to nonconducting level ratio of the signal which is produced at the output terminal T_2 at the aforesaid time of signal detection may be obtained at a high level such as 90 db. or more as shown by the actually measured value which is indicated by the dot-dash line in FIG. 3. Thus, it is possible to improve this level ratio by as much as about 40 db. as compared with the low values of 50–55 db. obtained with the conventional circuitries. Furthermore, in view of the fact that the resistance value between the drain and source electrodes of the FET Q_3 will increase as, for example, the slidable contact r_a of the variable resistor R_a is brought closer to the ground side. As a result, the transient time in the course of charge-up of the capacitor C_o, i.e., the sustain time of the electronic musical instrument, will become prolonged. Contrariwise, as the slidable contact r_a is brought closer to the power source $-V_d$ side, the resistance value between the drain and source electrodes of the FET Q_3 will decrease, so that the sustain time will become shortened.

As stated above, according to this instant embodiment, the two FET's which are connected in series to each other from both the DC and AC viewpoints are rendered simultaneously to either the conductive state or the nonconductive state via the key-operated switch S_o, so that the output signal which is detected via the serial circuit of these two FET's can be positively keyed or switched-over between on and off. Thus, it is possible to substantially improve the conducting to nonconducting level ratio of the signal as compared with the circuitry utilizing only one transistor of the ordinary type as shown in FIG. 1. Furthermore, since according to the present invention there are used field effect transistors in the sustain keyer circuit SA, the whole system will operate sufficiently even when a tone signal of a considerably large amplitude (such as the order of 10 V_{p-p} or more) is directly applied to the gate circuit of the FET Q_1, and in addition, the input impedance which is as high as several hundred kΩ may be easily obtained without paying any particular consideration such as the additional provision of a compensatory impedance. Thus, adverse effects such as an electric loss or a distortion of waveform can be altogether eliminated. Besides, in the instant embodiment, it is only necessary to provide no particular additional elements but only two FET's and resistance elements R and R_o in the sustain keyer circuit SA. Therefore, it is possible to eliminate the necessity for the use of a large number of resistors and a capacitor of a large capacity as is required in the prior art described above. This makes it extremely easy to effect integration of the sustain keyer circuitries in electronic musical instruments of the type described. Thus, the present invention is of a superior advantage of positively accelerating the tendency of making electronic musical instruments into compact size, which provides for a great merit industrially. Description has been made on an instance in which the control of the sustain effect according to the present invention is effected by both the capacitor C_o and the FET Q_3. It will be understood easily that this control may be performed by the application of a system of other type.

In the control of the sustain effect according to this instant embodiment, the transient characteristics in the courses of both beginning of conduction and of ending of conduction of the switching elements of such field effect transistors as FET Q_1 and FET Q_2 with which the tone signal in an electronic musical instrument is to be keyed are determined, respectively, so that the charge-up and/or the discharge transient phenomena of the capacitor C_o for determining the buildup and decay characteristics of the tone signal of the electronic musical instrument are caused to develop, respectively, through the resistance element R_o which is connected in parallel with said capacitor C_o and separately through the third FET Q_3 having a high inner impedance and being connected in series to said capacitor C_o and via the key-operated switch S_o which is adapted to close upon the depression of any selected keys of the keyboard of the electronic musical instrument. Along with this, the decay characteristic of the tone signal i.e., the sustain time characteristic of the electronic musical instrument can be controlled by first altering the inner resistance value between the drain and source electrodes of said FET Q_3 and whereby altering the transient characteristic of the capacitor C_o in the course of its charging-up. Accordingly, even when the capacitance of the capacitor C_o used is set to have a small value (for example, 0.1–0.5 microfarad), it is still sufficiently possible to obtain a sufficiently prolonged sustain time by causing the envelope of the waveforms during the charge-up time to follow a gradual down-going pattern. Thus, as compared with the high capacitance, such as 100 microfarads, of the capacitor C_2 assigned for determining the sustain time used in conventional electronic musical instruments, the capacitor C_o which is used in the instant embodiment may be of a capacitance as low as 1/500 of that of the capacitors in the conventional instruments. Accordingly it is possible to use capacitors of other types than electrolytic capacitors, that is to say, it is possible to employ paper capacitors or metallized paper capacitors of compact size. As a result, it is possible to minimize the variation of the static capacitance of the capacitor, and accordingly, to minimize the variation of the sustain time in the electronic musical instrument. In view of the fact also that the input impedances of the gate electrodes of the aforesaid FET's, Q_1 through Q_3, are markedly high, the variable resistor R_a for example, according to this embodiment, for altering the gate potential of the FET Q_3 assigned for determining the charge-up time of the capacitor C_1 is such that, by the provision of a single variable resistor R_a, it can alter the gate potentials of a large number of FET's accurately and stably, and thereby uniformly and simultaneously determine the sustain time of the electronic musical instrument. This not only will make it possible to reduce the number of such variable resistors used as compared with the conventional circuitries, but also will make it easy to integrate the circuitries since it is sufficient to use only two resistance elements in the circuitry according to this embodiment. As a result, it becomes possible to positively accelerate the reducing of the size of the electronic musical instruments. Besides, the aforesaid capacitor C_o may employ a paper capacitor or a metallized paper capacitor having a capacitance of the order ranging from 0.1 to 0.5 microfarad as stated above. Thus, there are a number of advantages such that the circuitry is produced in a markedly compact size and light in weight and at a low cost as compared with those utilizing electrolytic capacitors of a large capacity, so that this embodiment is of a great industrial value.

Description has been made on an instance in which the capacitor C_o is connected between the gate electrode and the power source $-V_d$ of the FET Q_2. In this instance, the variation of the gate potential of this FET Q_2 resulting from the keying operation of the key-operated switch S_o is exactly the same in fashion as that described above. However, the charge-up to discharging relative relation of the capacitor C_o will be the reverse of the relation described above. It should be understood also that, in the FET Q_1 and FET Q_2 according to this embodiment for keying the tone signal may employ switching elements of other types such as three-pole diodes, drift-type transistors, alloy-diffused transistors, and microalloy diffused transistors. Also, in this embodiment, description has been made on the instance in which two field effect transistors which are connected in series to each other are used. It should be understood easily that more than two switching elements, such as the field effect transistors, may be used by connecting them in series to effect the cutting-off and conducting switching of the tone signal.

Description will hereunder be made in detail on the embodiment shown in FIG. 4. The circuit arrangement embodying the invention is such, as shown in the block defined by the chain line in FIG. 4, that, of the three FET's, Q_{11}, Q_{12} and Q_{13}, the source electrode of one, FET Q_{13}, of them is grounded, and that a tone signal coming through an input terminal T_1 is ap-

plied to the gate electrode thereof, and that the drain electrode thereof is connected to the source electrode of another FET Q_{11} via the drain and source electrodes of the other FET Q_{12}, and that the drain electrode of said FET Q_{11} is connected to a power source $-V_d$ via a load resistance element R, whereas the gate electrode of this FET Q_{11} is connected in common to the gate electrode of the FET Q_{12}, and that a serial circuit consisting of a resistance element R_o and a key-operated switch S_o is interposed between the juncture of said common gate circuit and the power source $-V_d$, to thereby form a sustain keyer circuit SB so as to derive the tone signal from the drain of the FET Q_{11} and via said capacitor C and an output terminal T_2, upon the keying operation of said key-operated switch S_o.

It should be understood that said manner of connection of the gate circuits of the FET Q_{11} and the FET Q_{12} in the aforesaid arrangement may be altered to the manner in which, as shown in FIG. 5, the gate circuit of the FET Q_{11} is connected in common to the gate circuit of the FET Q_{13}, by substituting the FET Q_{12} by a FET Q_{13}, to form a sustain keyer circuit SB' so that the tone signal applied to the gate electrode of the FET Q_{12} may be derived at the output terminal T_2 via the drain circuit of the FET Q_{11} upon the keying operation of the key-operated switch S_o.

It should be understood that the capacitor C_o and the FET Q_o shown in FIGS. 4 and 5 represent a capacitor for determining the sustain time and another FET having its source electrode grounded and being used as a resistance element, respectively, and also that the sustain keyer circuits SB and SB' which are given within the blocks defined by the chain lines and said FET Q_o are to be provided in, for example, a console of an electronic musical instrument in a number corresponding to the number, for example, 90–100, of the tone generators which are provided in accordance with the keys of the keyboard of the electronic musical instrument. It should be understood further that the variable resistor R_a for adjusting the gate potential of the FET Q_o and whereby for determining the resistance value between the drain and source electrodes thereof is used only one in number in such a way that its slidable contact r_a is connected in common to the large number of gate circuits of the respective FET Q_o's which are used as the variable resistance elements of a correspondingly large number.

The circuit arrangement according to the instant embodiment for an electronic musical instrument is as described above. Description will hereunder be directed to the actions of this circuitry with respect to the embodiment shown in FIG. 4. The resistance elements R and R_o and the power source $-V_d$ are set beforehand so that, upon the keying operation, by the player or the user of the electronic musical instrument, of the key-operated switch S_o which is adapted to close in association with the depression applied to any selected keys of the keyboard during the playing, these resistors and the power source will assume such values as will render the FET's, Q_{11} through Q_{13}, to either the "cutoff" state or the "on" state, respectively. Also, the transient characteristics in the course of the beginning of conduction of the FET's, Q_{11} through Q_{13}, are arranged to be determined, when the key-operated switch S_o is closed, by the time constant which, in turn, is determined by the capacitance of the capacitor C_o and the resistance element R_o which are interposed in the gate circuits of the FET Q_{11} and the FET Q_{12} (meaning between the juncture *g* and the power source $-V_d$), to thereby determine the buildup characteristic of the tone signal detected at the output terminal T_2, whereas, when the key-operated switch S_o is opened, the transient characteristics in the course of the ending of conduction of the FET Q_{11}–FET Q_{13} are determined by the time constant which, in turn, is determined by such factors as the capacitance of the capacitor C_o and the drain-source resistance value of the FET Q_o, to thereby render the decay characteristic (so-called sustain time) of said detected signal to a desired characteristic. Furthermore, a tone signal having a predetermined frequency and a predetermined waveform and coming from a separately installed tone generator (which may be comprised of flip-flop circuits, but any known tone generator may be used, so that this is not shown in the drawings) is applied always to the input terminal T_1.

In the case where the FET Q_o is rendered to the "on" state while retaining its predetermined inner resistance value by adjusting the position of the slidable contact r_a of the variable resistor R_a, it is to be noted that in case the key-operated switch S_o is open, the juncture between the drain electrode of the FET Q_o and the gate electrodes of both the FET Q_{11} and FET Q_{12} in each set is at the ground potential. Accordingly, there is applied to these gate circuits no negative voltage which would render the FET Q_{11} and the FET Q_{12} to the "on" state, with the result that these FET's are held in their "cutoff" state. Also, the other FET Q_{13} which is connected to the source electrode of the FET Q_{12} is rendered to the "cutoff" state because there is applied no negative voltage to the drain electrode of this FET Q_{13}. After all, all of the three FET's, Q_{11} through Q_{13}, which are connected in series are held in their shut-off state, and accordingly, the leakage current (dark current) between the drain and source circuits of these FET's is minimal, being of the order of 10^{-9} (1 nano-ampere), and also, the static capacity between the drain and the source circuits of these FET's is markedly small as compared with that obtained in ordinary transistors. Besides, in view of the fact that these three FET's are connected in series from both AC and DC viewpoints, the aforesaid capacity will reduce to approximately ⅛. Therefore, the tone signal which is always applied to the gate circuit of either the FET Q_{13} or FET Q_{12} (see FIG. 5) will hardly be produced at the drain side of the FET Q_{11}. As a result, the switching ratio (signal conducting to nonconducting ratio or S/N ratio) may be obtained at a large level as 100 db. or more as shown by the actually measured value which is indicated by the solid line *b* in FIG. 7.

On the other hand, when the key-operated switch S_o is closed, the charge on the capacitor C_o which has been in the charged-up state in the aforesaid stage by the resistance element R_o which is connected in series to this key-operated switch S_o is discharged, and along with this, the potential of the juncture *g* between the gate circuits of both the FET Q_{11} and the FET Q_{12} and the drain circuit of the FET Q_o approaches the potential of the power source $-V_d$. As a result, both the FET Q_{11} and the FET Q_{12} are first rendered to the "on" state, and then, almost simultaneously therewith, the FET Q_{13} will also be rendered to the "on" state, so that the tone signal which is applied to the gate circuit of this FET Q_{13} is detected at the output terminal T_2 via the drain circuit of said FET Q_{13} and via the source and drain circuits of the FET Q_{12} and the FET Q_{11}, respectively, in this order. By, for example, amplifying this detected tone signal, it is possible to obtain auditory sound wave of the converted tone signal through a speaker or like appliances.

When the key-operated switch S_o is opened again, the capacitor C_o which has been in the discharged state in the aforesaid stage begins to be charged up with the voltage of the power source $-V_d$ via the FET Q_o, and also the potential of the juncture *g* between the gate circuits of the FET Q_{11} and the FET Q_{12} and the drain circuit of the FET Q_{13} approaches the ground potential. When the potential in each set rises above (meaning more positive than) a predetermined potential, both the FET Q_{11} and the FET Q_{12} are rendered to the "cutoff" state first of all, and then almost simultaneously therewith, the FET Q_{13} will also be rendered to the "cutoff" state, with the result that these three FET's will be rendered to the shut-off state, respectively, as in the preceding case where the key-operated switch S_o is opened. Accordingly, the tone signal which is applied to the input terminal T_1 is almost completely shut off by these FET's after the lapse of a sustain time which is determined by the time constant which, in turn, is determined by the capacitance of the capacitor C_o and the inner resistance value of the FET Q_o, so that the tone signal is no longer detected at the output terminal T_2. In this case, the output signal switching ratio (signal level ratio) which is derived

at the output terminal T_2 at the aforesaid time of detection of the tone signal may be obtained in such a high level as 100 db. or more as shown by the solid line *b* in FIG. 7. Thus, it is possible to improve the value of this ratio by about 10 db. as compared with that obtained from other circuitry shown in FIG. 2.

It should be noted that, in case the connection shown in FIG. 4 of the gate circuits of both the FET Q_{12} and the FET Q_{13} is replaced in the manner as shown in FIG. 5, it is likewise possible to obtain a high level, such as 100 db. or more as shown by the solid line *b* in FIG. 7, of output signal switching ratio with which the tone signal applied to the gate circuit of the FET Q_{12} via the input terminal T_1 is to be derived from the drain circuit of the FET Q_{11}. In this case, however, the source circuit of the FET Q_{12} is cut off from the ground owing to the cutting-off of the respective FET's, especially owing to the cutting-off of the FET Q_{13}, and accordingly, no effective input signal becomes to be applied to the gate-source circuit of this FET Q_{12}, so that the signal switching ratio is considered to be improved.

With respect to the arrangement of sustain keyer circuit SC shown in FIG. 6 in which five FET's, Q_{11}–$_{Q15}$, are connected in series, so that an input signal is applied to the gate circuit of one, meaning FET Q_{13}, of these five FET's and that the output signal is adapted to be derived from the drain circuit of the FET Q_{11}, the signal switching ratio can be improved further to the order of 110–120 db. as shown by the dotted line *c* in FIG. 7.

As described above, according to this embodiment, three or more FET's which are connected in series can be rendered simultaneously to either the "on" state or the "cutoff" state via the key-operated switch S_o, and the output signal which is detected after being passed through the serial circuits of these FET's can be positively keyed. As a result, it is possible to improve the signal switching ratio by 10–20 db. as compared with the circuitry of this type shown in FIG. 2 in which only two FET's are used. Also, even when there arises a drop of insulation or short-circuiting in the respective FET's, it is still possible to positively retain a sufficiently large signal switching ratio. Thus, the instant embodiment is able to greatly improve the safety of the sustain keyer circuit which constitutes the principal section of an electronic musical instrument. It should be noted further that, in circuitries of this type, an increase in the number of FET's will never hamper the integration of the circuitries and that, even where there is some increase in the area occupied by these FET's, such an inconvenience may be overcome to a great extent by many superior advantages such that a safety operation can be insured, and thus, this embodiment is of a great industrial merit.

Description has been made on the instance in which the control of the sustain effect is effected by the capacitor C_o and the FET Q_o. It should be apparent that this controlling may be effected by the use of systems of other types.

Description will hereunder be made on some other embodiments of the sustain keyer circuit shown in FIGS. 8 through 10. This circuit employs pairs of FET's which are connected in parallel to the FET's, respectively, which are used as the switching elements in the circuits shown in FIGS. 4 to 6 which represent the preceding embodiments of the invention. The instant embodiments are insured for positive and safe operation of the circuitries even when there arises a drop of insulation and a short-circuiting or opening of circuit in each of the FET's. Accordingly, the instant embodiments are of essentially the same arrangement with that of said preceding embodiments, and the actions of the circuitries are substantially the same also, so that their detailed explanation is omitted.

Next, description will be directed to still another embodiment in which three FET's are used in place of one FET in the sustain control circuit shown in FIG. 2, by referring to FIG. 11.

First, in FIG. 2, when the key-operated switch S_o is opened again at the time t_1 in FIG. 13, the capacitor C_o which has been in the discharged state in the aforesaid preceding stage begins to be charged up with the voltage of the power source $-V_d$ via a relatively large predetermined inner resistance between the drain-source circuits of the FET Q_o, and the potential of the juncture between the gate circuit of the FET Q_2 and the drain circuit of the FET Q_o approaches the ground potential. Also, when the potential of this juncture in each set rises above (meaning more positive than) a predetermined potential at the time t_1 or t_2 in FIG. 13, the FET Q_2 is rendered to the "cutoff" state first of all, and then, almost simultaneously therewith, the FET Q_1 is also rendered to the "cutoff" state, so that these two FET's are rendered to the shutoff state as in the case in which the aforesaid key-operated switch S_o is in the opened state. Thus, the tone signal which is applied to the input terminal T_1 is almost completely shut off by these FET's at the end of lapse of the sustain time which is determined by the time constant which, in turn, is determined by the capacitance of the capacitor C_o and the inner resistance of the FET Q_3. Accordingly, there will no longer be detected a signal at the output terminal T_2. In view of the fact that the resistance value between the drain and source circuit of the FET Q_3 increases as, for example, the variable voltage source represented by contact r_a is brought closer toward the ground potential zero, the transient length of time of charging up of the capacitor C_o, i.e., the sustain time of the electronic musical instrument, is prolonged to the length of time from t_o to t_2 as shown by the chain line in FIG. 13. Contrariwise, as r_a approaches closer toward the negative voltage of the other power source $-V_d$, the resistance value between the drain-source circuits of the FET Q_3 reduces so that the sustain time will accordingly decrease to the length of time from t_o to t_1 in FIG. 13. Accordingly, it is possible to control, with a relative easiness, the sustain time of an electronic musical instrument. In the embodiment shown in FIG. 2, however, owing to the nonrectilinear characteristic of the FET Q_3, the decay characteristic of the tone signal within said sustain time will show an upwardly convexed curve as shown by the envelope curve in FIG. 13, which gives an unnatural ending of the audible sound during the decay thereof in an electronic musical instrument, and therefore, this is not desirable. It is, therefore, the object of this instant embodiment to solve the foregoing inconvenience and drawback. This embodiment will hereunder be described in detail by referring to FIG. 11. It should be understood that the portion given in the block defined by the chain line in FIG. 11 represents a sustain keyer circuit SA' which is arranged in the same manner as the sustain keyer circuit SA given in the block defined by the chain line in FIG. 2. The gate circuit of the FET Q_2 given in this block is grounded via the drain electrode and the source electrode of the serially arranged FET Q_3 and FET Q_4, respectively, in this order, and also said gate circuit of the FET Q_2 is connected to the gate circuit of the FET Q_3. The gate circuit of this FET Q_3 is connected to the drain circuit of another FET Q_5 having its source electrode grounded. The gate circuit of this latter FET Q_5 is connected to a fixed bias power source $-V_{d2}$ which is of a voltage somewhat lower than that of the supply power source $-V_{d1}$ of the aforesaid sustain keyer circuit SA'. Furthermore, the gate circuit of said FET Q_4 is connected to a variable voltage source $-V_c$.

It should be understood that the sustain keyer circuit SA' given in the block defined by the chain line in FIG. 11 and said FET's, Q_3 to Q_5, are provided, respectively, in, for example, a console of an electronic musical instrument and in a number corresponding to the large number of tone generators which are provided in accordance with the number of the keys of the keyboard of the electronic musical instrument. Whereas, the power sources $-V_{d1}$, $-V_{d2}$ and $-V_c$ are provided only one each so as to be connected in common to the large number of sustain keyer circuits and the correspondingly large number of FET's, Q_3 to Q_5.

Description will hereunder be made on the action of the sustain time control circuit of this embodiment. In case the power sources $-V_{d2}$ and $-V_c$ are set to have predetermined voltages and in case said FET Q_3–FET Q_5 have predetermined values of impedance between the drain-source circuits,

respectively, the junction between the drain circuit of the FET Q_3 and the gate circuit of the FET Q_2 is at the ground potential in each set. Accordingly, there is applied to this gate circuit no negative voltage which would render the FET Q_2 to the "on" state, so that this FET Q_2 is in its "cutoff" state. Also, the FET Q_1 which is connected to the source circuit of said FET Q_2 is in its "cutoff" state because there is applied no negative voltage to the drain circuit of this FET Q_1. After all, these two FET Q_1 and FET Q_2 which are connected in series are held in their shutoff state. As a result, the tone signal which is applied always to the gate circuit of this FET Q_1 will not produce on the drain side of the FET Q_2. It should be understood that the capacitor C_o which is connected to the gate circuit of the FET Q_2 is in the state of being charged up with the voltage of the power source $-V_{d1}$ via the predetermined inner resistances between the drain-source circuits of the other FET's, Q_3, Q_4 and Q_5.

On the other hand, when the key-operated switch S_o is closed, the charge on the capacitor C_o which, in the aforesaid stage, has been charged up is discharged through the resistance element R_o which is connected in series to said key-operated switch S_o, and also, the potential of the juncture between the gate circuit of the FET Q_2 and the drain circuit of the FET Q_3 approaches the negative potential of the power source $-V_{d1}$. As a result, the FET Q_2 will be rendered to the conductive state first of all, and then, almost simultaneously therewith, the FET Q_1 will also be rendered to the conductive state. As a result, the tone signal which is being applied to the gate circuit of this FET Q_1 is detected at the output terminal T_2 via the drain circuit of said FET Q_1 and the source and drain circuits of the FET Q_2 successively in this order. By, for example, amplifying this detected signal, it is possible to obtain, through a speaker or like appliances, an audible sound wave having been converted from the tone signal.

Next, when the key-operated switch S_o is opened again at the time t_o shown in FIG. 12, the capacitor C_o which has been in the discharged state in the preceding stage begins to be charged up with the voltage of the power source $-V_{d1}$ via the predetermined inner resistances between the respective drain and source circuit of the FET's, Q_3–Q_5, and the gate potential of the FET Q_2 and the drain potentials of the FET Q_3 and FET Q_5 approach the ground potential, respectively. When these potentials rise above (meaning more positive than) a predetermined potential at the time t_1 or t_2 shown in FIG. 12, the FET Q_2 and the FET Q_1 are both rendered nonconductive. Thus, these two FET's are shut off in the same manner as described in connection with the instance where the key-operated switch S_o is in the opened state. As a result, the tone signal which is being applied to the input terminal T_1 is shut off by these two FET's, Q_2 and Q_1, at the end of a lapse of the sustain time (t_1 or t_2) which is determined by the time constant which, in turn, is determined by the capacitance of the capacitor C_o and the respective apparent drain-source resistances of the FET's, Q_3–Q_5, mainly the FET Q_3 and FET Q_4. Thus, there is no longer detected the tone signal at the output terminal T_2.

It should be understood that the aforesaid sustain time is such that a desired sustain effect may be obtained by varying the DC potential of the gate circuit of the FET Q_4 resulting from the adjusting of the voltage of the variable voltage source $-V_c$. In view of the fact, however, that, in such a case, the drain-source resistance value of the FET Q_4 will increase as, for example, the aforesaid voltage of the voltage source $-V_c$ approaches closer toward the ground potential zero, the transient current—during the charging-up of the capacitor C_o—which flows through the drain-source resistance of the FET Q_3 which is connected in series to said FET Q_4 will become limited. As a result, the transient time during the charging up of this capacitor C_o will become prolonged. Accordingly, under such a condition, the sustain time of the tone signal which is detected at the output terminal T_2 will be as lengthy as the period of time from t_o to t_2 as indicated by the straight chain line in FIG. 12. Contrariwise, as the voltage of the variable voltage source $-V_c$ approaches closer toward the voltage of the fixed voltage source $-V_{d1}$, the drain-source resistance value of the FET Q_4 will decrease. Accordingly, the limitation which has been imposed on the transient current—during the charging-up of the capacitor C_o—which flows via the drain-source resistance of the FET Q_3 which is connected in series to said FET Q_4 is lightened so that the duration of the transient time during the charging up of the capacitor C_o is reduced. As a result, the sustain time of the tone signal will become shortened to the length of time from t_o to t_1 as indicated by the solid straight line in FIG. 12. Thus, it is possible to control the sustain time of the electronic musical instrument by altering the gate potential of the FET Q_4. It should be noted that, especially in this instant embodiment, the transient time during the charging-up of the capacitor C_o assigned for determining the sustain time is controlled via the serial drain-source circuit of the FET Q_4 which is used as the main variable resistance element and the similar circuit of the FET Q_3 which serves as the variable resistance load for correcting the nonrectilinear voltage to current characteristic of said FET Q_4, and also that the current flowing through said FET Q_3 is controlled in such a manner as will correct the nonrectilinear voltage to current characteristic of the FET Q_4 which is used as the main variable resistance element, via the FET Q_5 which is connected in parallel to the gate circuit of the FET Q_3 and also to the ground, and further that, whereby the decay characteristic of the tone signal within the aforesaid sustain time can be rendered rectilinear as shown by the straight envelope line in FIG. 12. Thus, it is possible to obtain the optimum acoustic exponential decay curve.

As stated above, according to this instant embodiment, the current for charging up the capacitor C_o assigned for determining the sustain time of an electronic musical instrument is controlled via the drain-source circuits of the FET Q_4 which performs rectilinear action and of the FET Q_3 which serves as the load of said FET Q_4 successively in this order to thereby increase or decrease the transient time during the charging up of said capacitor C_o. Whereby, it is possible to control the sustain time of the electronic musical instrument as desired, and also it is possible to obtain the envelope curve of the sustain time always in the form of the optimum exponential decay curve regardless of the manner of this control. Therefore, according to this embodiment, it is possible to completely eliminate the unnaturalness of the decay pattern of the tone signal which would be encountered to some extent in such circuitries of this type as the one shown in FIG. 2. Thus, the instant embodiment may be most desirably applied to the sustain time control unit of electronic musical instruments. Also, in view of the fact that the sustain time control system may be obtained without the provision of any additional resistance elements in the circuitry of the instant embodiment, the latter embodiment is of a number of superior advantages such that the integration of the circuitries can be attained easily, in addition to the foregoing advantage. Thus, this embodiment is of a great industrial value.

In the aforesaid embodiment, description has been made on the instance in which the capacitor C_o is connected between the gate circuit of the FET Q_2 and the power source $-V_{d1}$. It should be understood, however, that this capacitor C_o may instead be connected between the gate circuit of the FET Q_2 and the ground point. In such an instance, the variation of the gate potential of the FET Q_2 resulting from the keying operation of the key-operated switch S_o is effected in the same way as in the aforesaid embodiment, but the relation between charging up and discharging of the capacitor C_o will be the reverse of that of said embodiment.

Next, description will be made on still another embodiment, shown in FIG. 14, of the sustain time control circuit. This is an improvement of the embodiment shown in FIG. 11. More specifically, in the embodiment shown in FIG. 11, there is the necessity for additional provision of a DC source separately from the main power source $-V_{d1}$ in view of the need for a fixed voltage source $-V_{d2}$ for biasing the gate circuit of the FET Q_5. To this end, there will be portions in the circuitry in

which are employed various electric parts such as a bleeder resistor and a decoupling capacitor. This will inevitably lead to an increase in the size of the aforesaid particular portions of the power source circuits as a whole and will accordingly lead to an increase in the cost of the system as a whole. Furthermore, there will be required a number of lead wires for use in the connection of said voltage source $-V_{d2}$ to said FET Q_5 since this FET has to be provided in a number which is approximately 90–100 in one electronic musical instrument as stated previously. This will lower the efficiency in the fabricating operation of the circuitries and will greatly hamper the mass productivity of electronic musical instruments. Thus, the embodiment shown in FIG. **11** has a number of drawbacks. To eliminate these drawbacks, the embodiment shown in FIG. **14** provides the following arrangement. That is to say, in place of FET Q_5, the gate circuit of the FET Q_o is connected to the fixed voltage source $-V_d$ which, in turn, is connected to the sustain keyer circuit SA', and also the source circuit of said FET Q_o is connected in common to the source circuit of the FET Q_3. Accordingly, this FET Q_o does not require a separate gate-biasing voltage source, and yet it is possible to effect correction of the action of this FET so as to have a desired rectilinear characteristic as described in connection with FIG. **12**.

Next, description will be directed to yet another embodiment of the sustain time control circuit by referring to FIG. **15**. Like the embodiment shown in FIG. **14**, the instant circuitry in FIG. **15** shows an arrangement with the omission of one power source assigned for biasing the FET in FIG. **11**. More specifically, the difference of this instant embodiment from the circuitry shown in FIG. **11** lies in the following arrangement. The FET Q_5 is connected in series to another FET Q_6, whereas the gate circuit of said FET Q_5 is connected in common to the gate circuit of the aforesaid FET Q_4, and this common gate circuit is connected to a variable voltage source $-V_c$. Also, the gate circuit of the FET Q_6 is connected to a fixed voltage source $-V_d$ which, in turn, is connected to the aforesaid sustain keyer circuit SA'. In this circuit arrangement, the sustain time is such that a desired sustain effect like the one described in connection with FIG. **12** can be obtained by adjusting the voltage of the variable voltage source $-V_c$ and whereby altering the gate DC levels of both the FET Q_4 and FET Q_5 simultaneously and in the same direction.

Furthermore, it is possible, in this embodiment, to omit the fixed power source $-V_{d2}$ for biasing the FET Q_5 which is assigned for correcting the action of the FET Q_4 into rectilinear characteristic. Accordingly, this will altogether eliminate the use of a number of lead wires (not shown) which would otherwise have to be provided between the circuits of this type and the bias voltage source. As a consequence, the workability of the manufacture of electronic musical instruments having circuitries of this type will greatly improve to become suitable for mass production of such instruments. Also, the fact that no provision of additional resistance elements is necessary will permit an easy integration of the circuitries.

I claim:

1. In an electronic musical instrument, a sustain keying circuit comprising:

an input terminal for receiving an input tone signal from a tone generator,

an output terminal for providing a keyed output tone signal having desirable sustain characteristics,

first and second active elements, each having first and second electrodes and a control electrode for controlling current flow between said first and second electrodes,

said first electrode of said first active element being connected to said second electrode of said second active element, of said first and second active elements being electrically connected together in series and this series arrangement also being connected in series with a load resistor and a power source,

said control electrode of said first active element being electrically connected to said input terminal,

said load resistor being electrically connected to said output terminal, and

keying means including a key-operated switch connected to the control electrode of said second active element, said means producing a controlled tone buildup and a decay sustain characteristic which is produced after key activation and deactivation respectively while yet severely limiting undesirable tone feed through to the output terminal under quiescent circuit conditions.

2. A sustain keying circuit as in claim **1** wherein said keying means includes a capacitor connected between the control electrode of said second active element and an AC ground.

3. A sustain keying circuit as in claim **2** wherein said keying means further includes:

a third active element having first and second electrodes and a control electrode,

said first electrode of said third active element being connected to said control electrode of said second active element,

said second electrode of said third active element being electrically connected to one terminal of said power source, and

said control electrode of said third active element being connectable to a source of variable voltage whereby the sustain characteristics of said keying circuit may be varied as desired by varying said variable voltage.

4. A sustain keying circuit as in claim **1** further comprising:

a third active element having first and second electrodes and a control electrode,

said first and second electrodes of the third active element being electrically connected in series with the first and second electrodes of the first and second active elements, and

the control electrode of said third active element being connected in common with the control electrode of the second active element whereby even less undesirable tone feed through is produced while also increasing the reliability of the keying circuit.

5. A sustain keying circuit as in claim **1** wherein each of said first, second and third active elements is provided with another active element connected in parallel therewith via electrical connections between respectively similar electrodes of each resulting pair of active elements.

6. A sustain keying circuit as in claim **3** further comprising:

fourth and fifth active elements each having first and second electrodes and a control electrode,

said first and second electrodes of said fourth active element being connected in series with the first and second electrodes of said third active element,

the control electrode and the first electrode of said fourth active element being connected together to cause the fourth active element to serve as a variable resistance for correcting nonlinearities in the sustain characteristics of said keying circuit, and wherein

the first and second electrodes of said fifth active element are connected from said control electrode of the fourth active element to groud with the control electrode of the fifth active element connectable to a power source whereby the characteristic decay envelope of the keyed output is exponentially shaped.

7. A sustain keying circuit as in claim **3** further comprising:

fourth and fifth active elements, each having first and second electrodes and a control electrode,

said first and second electrodes of said fourth active element being connected in series with the first and second electrodes of said third active element with the control electrode and the first electrode of said fourth active element being connected together to cause the fourth active element to serve as a variable resistance for correcting nonlinearities in the sustain characteristics of said keying circuit, and wherein

the first and second electrodes of said fifth active element are connected to the first and second electrodes respec-

tively of the fourth active element with the control electrode of the fifth active element connectable to said power source in common with said load resistor.

8. A sustain keying circuit as in claim 3 further comprising:

fourth, fifth and sixth active elements, each having first and second electrodes and a control electrode,

said first and second electrodes of said fourth active element being connected in series with the first and second electrodes of said third active element with the control electrode and the first electrode of said fourth active element being connected together to cause the fourth active element to serve as a variable resistance for correcting nonlinearities in the sustain characteristics of said keying circuit, and wherein

the control electrode of said fifth active element being connected to the control electrode of said third active element,

the first electrode of said fifth active element being connected to the control electrode of said fourth active element,

the second electrode of said fifth active element being connected to the first electrode of said sixth active element,

the second electrode of said sixth active element being grounded, and

the control electrode of said sixth active element being connectable to said power source in common with said load resistor.

9. A sustain keying circuit as in claim 1 wherein said active elements comprise field effect transistors with said first, second and control electrodes corresponding to drain, source and gate electrodes respectively.

10. A sustain keying circuit as in claim 1 wherein said active elements comprise three-pole diodes.

11. A sustain keying circuit as in claim 1 wherein said active elements comprise drift-type transistors.

12. A sustain keying circuit as in claim 1 wherein said active elements comprise alloy-diffused transistors.

13. A sustain keying circuit as in claim 1 wherein said active elements comprise microalloy diffused transistors.

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