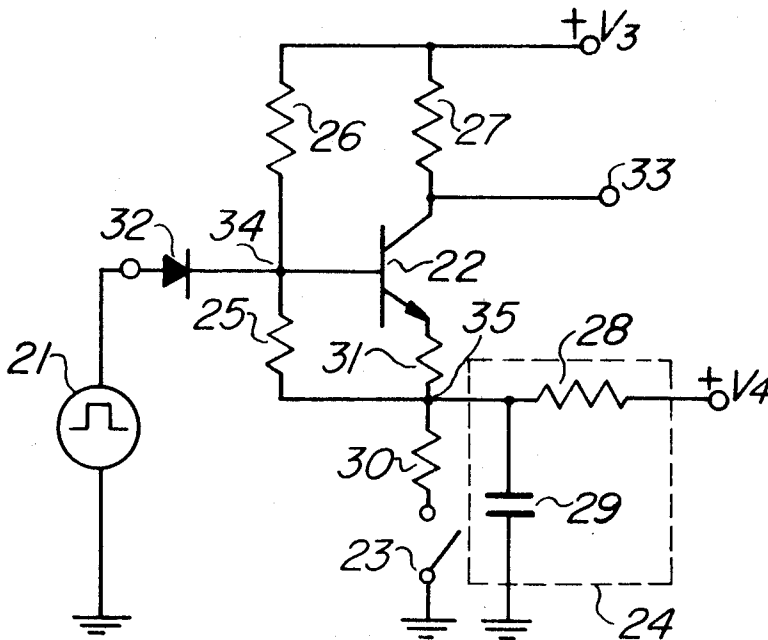


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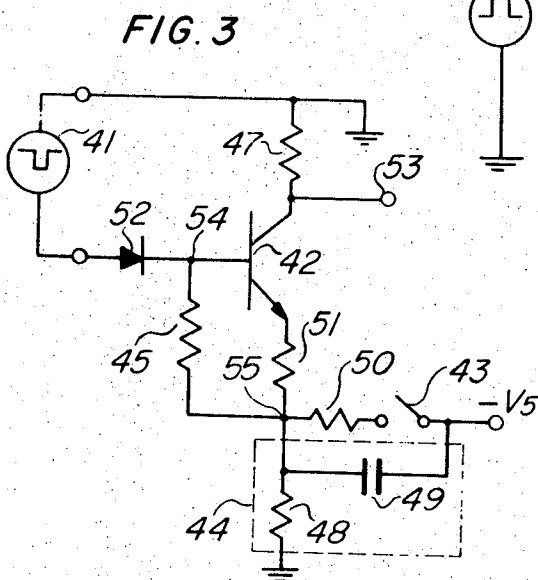
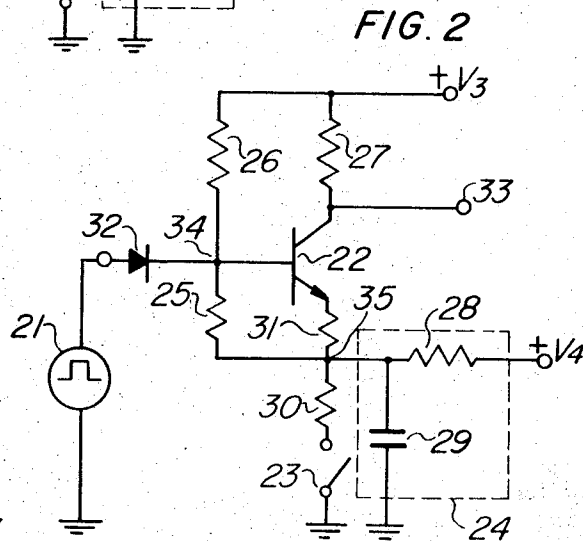
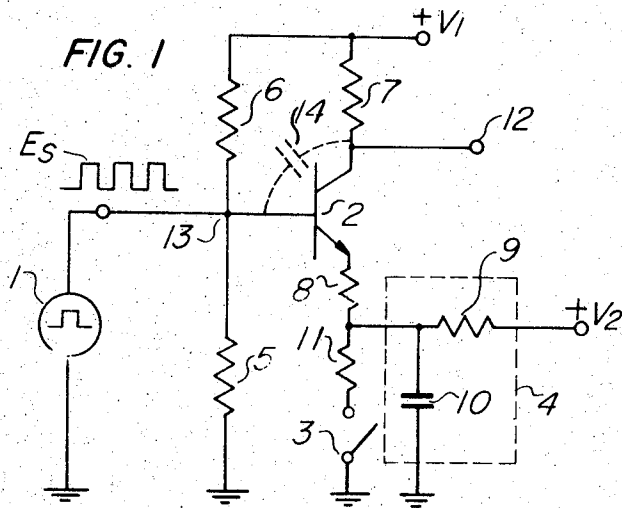
[54] **SWITCHING DEVICE FOR ELECTRONIC MUSICAL INSTRUMENT WITH SUSTAIN EFFECT**
4 Claims, 3 Drawing Figs.
[52] U.S. Cl..... 84/126
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[50] Field of Search..... 84/1.04,
1.08, 1.13, 1.24, 1.26; 307/293

ABSTRACT: A switching device for electronic musical instrument, comprising a transistor, a CR time-constant circuit for producing a sustain effect, and a PN junction diode connected with the base electrode of said transistor in the same conducting direction as the emitter-base junction of said transistor, wherein an input signal is supplied to said base electrode and an output signal is taken from the collector electrode of said transistor.



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SWITCHING DEVICE FOR ELECTRONIC MUSICAL INSTRUMENT WITH SUSTAIN EFFECT

This invention relates to improvements in a switching device for an electronic musical instrument.

In general, an electronic musical instrument uses such a system that a number of signals of different frequencies are suitably selected by actuating keys arranged in a keyboard which are associated with a switching device, and the signals thus selected are combined or mixed with each other to produce a desired musical tone. In accordance with a conventional example, the switching device of this type comprises an electronic amplifying element, a manual switch such as a key switch for controlling said electronic amplifying element, and a "sustain" circuit or envelope forming circuit for producing a sustained attenuation effect (referred to as "sustain" effect) for an output signal. Such device is a kind of gate circuit device, as will be described later, which is also referred to as sustain gate circuit. The feature of such switching device is that there is obtained an output signal of which the amplitude is attenuated not momentarily but gradually by the actuation of said keys.

In an electronic musical instrument using the above switching device, however, there is a tendency that a leakage signal occurs at the output terminal of the switching device when the manual switch is opened or when the instrument is not played, thus resulting in noise which can not be neglected. This has become a serious problem with an electronic musical instrument.

It is an object of this invention to provide a novel and improved switching device for an electronic musical instrument, which is capable of minimizing a leakage signal.

Another object of this invention is to provide a miniaturized switching device using a transistor.

Still another object of this invention is to provide a switching device using a transistor, which is so designed as to prevent the transistor from being damaged.

In accordance with the present invention, an unsymmetrical type of an element such as a PN junction diode (an element of which the forward voltage-current characteristic is unsymmetrical with respect to the backward characteristic) is coupled to the input circuit of an amplifier element such as a transistor, whereby the above objects can be accomplished. The amplifier element and unsymmetrical type element are provided with a first or a second bias condition by biasing means in accordance with the opening or closing operation of switch means such for example as a key switch, respectively. Under the first bias condition, the unsymmetrical type element is biased in the reverse direction, and the amplifier element is so biased that its gain becomes substantially zero. Under the second bias condition, on the other hand, said unsymmetrical type element is biased in the forward direction, and the amplifier element is so biased that its gain assumes a predetermined value. Furthermore, a time-constant circuit for delaying the switching of the bias condition for a predetermined period of time is combined with the biasing means and switch means, whereby said switch means is switched from "on" to "off".

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

FIG. 1 is a circuit diagram showing a conventional switching device for use with an electronic musical instrument;

FIG. 2 is a circuit diagram showing the switching device for an electronic musical instrument according to a first embodiment of the present invention; and

FIG. 3 is a circuit diagram showing the switching device for an electronic musical instrument according to a second embodiment of the present invention.

Referring to FIG. 1, there is shown a conventional switching device, wherein the reference numeral 1 represents a tone generator, 2 a transistor, 5 and 6 bias resistors, 7 a load resistor, and 8 an emitter resistor. A circuit 4 is a circuit for producing the "sustain" effect, which is constituted by a resistor 9 and a capacitor 10. $+V_1$ represents a power source for

operating the transistor 2, and $+V_2$ denotes a power source for affording a reverse bias to the emitter of the transistor. The reference numeral 3 represents a key switch which is closed by depressing the key, 11 a resistor, and 12 an output terminal. A resistor is usually connected between the tone generator 1 and the node 13, though it is not shown in FIG. 1.

In operation, initially the emitter-base junction of the transistor 2 is deeply reverse biased by the power source $+V_2$, with the key switch being maintained in the open state. Thus, even if an input signal voltage e_i is supplied from the tone generator 1 to the transistor 2, the latter is normally rendered nonconductive with respect to the input signal voltage, so that the input signal voltage e_i is substantially not transmitted to the output terminal 12. However, a slight leakage signal appears at the output signal 12. It is presumed that such leakage signal is produced by the fact that the input signal voltage e_i is transmitted to the output terminal 12 through the barrier capacitance 14 between the collector and the base of the transistor 2.

Subsequently, by closing the key switch 3, the emitter-base junction of the transistor 2 is biased slightly in the forward direction so that the transistor is permitted to perform a normal switching operation, thus transmitting the input signal voltage e_i to the output terminal 12.

In the foregoing switching device, the transistor is switchingly rendered nonconductive or conductive by opening or closing the key switch 3, thereby performing the switching operation with respect to the signal from the tone generator, as described above. However, such conventional device has such a serious drawback that in case it is incorporated in a musical instrument such as an electronic organ which has a number of keys, a signal tone from a tone generator is likely to be heard even when no key is depressed, due to the fact that the "opening-closure" ratio (ratio S_{on}/S_{off} of the level S_{on} of an output signal which is obtained at the output terminal 12 when the key switch 3 is closed to the level S_{off} of a leakage signal which occurs at the output terminal 12 when the key switch 3 is opened).

Furthermore, signal e_i from the tone generator 1 is always supplied to a node 13, and the emitter breakdown voltage of the transistor is not too high. As a result, there is a tendency that the emitter junction of the transistor breaks down easily.

The present invention intends to eliminate the above drawbacks of the conventional device. In accordance with an embodiment of the present invention, an unsymmetrical element such as a diode is inserted in the base circuit of a transistor, and there is provided a means for biasing said diode in the reverse or forward direction in accordance with the open or closed state of a switch means such as a key switch. Thus, when the key switch is in the open state, the diode represents a high impedance whereby a signal which is actually supplied to the base of the transistor is remarkably attenuated. Such signal attenuation contributes to an increase of the opening-closure ratio and reduction of the emitter junction breakdown trouble.

FIG. 2 shows the device according to a first embodiment of this invention, wherein reference numeral 21 represents a tone generator for generating a rectangular wave signal, 32 a PN junction diode connected with the generator, 22 an NPN transistor to the base electrode of which is supplied said signal through the diode 32, and 27 a load resistor having one end thereof connected with a positive potential source $+V_3$ and the other end thereof connected with the collector electrode of the transistor and an output terminal 33. Reference numeral 24 denotes an envelope forming circuit consisting of a resistor 28 and a capacitor 29 and connected with the emitter electrode of the transistor through an emitter resistor 31, and 23 a key switch connected with the emitter of the transistor through resistors 30 and 31 for controlling the bias conditions for the transistor and diode. Reference numerals 25 and 26 indicate bias resistors for the transistor, and $+V_4$ a power source for operating said envelope forming circuit and biasing the diode 32 in the reverse direction through resistors 25 and 28 when the key switch is opened.

Description will now be made of the operation of the present switching device or "sustain" gate circuit. First, when the switch 23 is opened, the diode 32 is biased in the reverse direction through the resistors 25 and 28 by the potential source $+V_4$, having a positive potential selected above the peak value of the input signal voltage. Capacitor 29 is charged substantially to $+V_4$ (V), and the potential at the node 35 is substantially $+V_4$ (V). The potential $+V_3$ (V) is selected to be close to or lower than the potential $+V_4$ (V). That is, the transistor 22 is so biased that it may operate in the cut-off region or a low current level region in the neighborhood of the cut-off region so that the gain thereof becomes substantially zero. A signal which has been attenuated by the high impedance of the diode biased in the reverse direction is applied to the node 34 coupled to the base of the transistor 22, since the impedance between the node 34 and the ground potential or reference potential point is lower than the backward impedance of the diode. Thus, the attenuated signal does not cause the breakdown of the emitter junction and is substantially prevented from being transmitted to the output terminal 33, unlike in the conventional case.

Thereafter, if the switch 23 is closed, then the potential at the node 35 becomes equal to the ground potential in a short period of time which depends upon the product of the capacitance of the capacitor 29 and the resistance of the resistor 30, since the resistance of the resistor 30 is selected to be very low as compared with the resistance of the resistor 28. At this time, the diode is biased in the forward direction, and the operating point for the transistor 22 is so selected as to fall within the active region thereof, whereupon the transistor starts the amplifying operation with a predetermined gain so that the signal from the tone generator is transmitted to the output terminal 33. The diode will by no means hinder such signal transmission since it is biased in the forward direction as described above.

Subsequently, the switch 23 is again returned to the open state. At this time, the potential at the node 35 is not immediately returned to the initial value or substantially $+V_4$ (V). More specifically, the potential at the node 35 continues to increase gradually in accordance with the charging characteristic of the capacitor 29 which is substantially dependent upon the product RC (referred to as time-constant) of the resistance R of the resistor 28 and the capacitance C of the capacitor 29. When the potential at the node 35 reaches $+V_4$ (V), each of the diode 32 and transistor 22 will be provided with the initial bias condition so that the signal will be prevented from being transmitted to the terminal 33.

Thus, the transistor 22 will not be provided with the initial bias condition upon the opening of the switch 23. That is, when the switch is opened, the bias condition for the transistor will be gradually changed from that which has been imparted thereto with the switch being closed to the steady bias condition by way of a predetermined transient state, so that an output signal will be held at the terminal 33 for a predetermined period of time even if the switch is opened. The amplitude of the output signal thus held will be substantially exponentially attenuated in accordance with the transient characteristic of the foregoing time-constant circuit or envelope forming circuit, so that a so-called envelope is formed in the output signal. In any electronic musical instrument, such envelope signal is essential to the production of a natural tone. It is for the purpose of producing such an envelope signal that use is made of the combination of a key switch with an electronic amplifier element and an envelope forming circuit rather than a key switch alone, as described above.

The reason for the increase of the opening-closure ratio can be explained as follows: a sort of high-pass filter is equivalently constituted by the capacitance between the electrodes of the diode 32 and the impedance between the node 35 and the ground point, so that the lower order harmonic components of the rectangular wave from the generator 21 are cut off by the filter circuit while the higher order ones are permitted to pass therethrough. The higher order harmonic components thus passed are again filtered by a high-pass filter comprising the

collector barrier capacitance and the impedance between the terminal 33 and the ground point, before they reach the output terminal 33. In this way, only a small amount of extremely high order harmonic components will appear at the output terminal 33. A signal containing such high order harmonic components has not sufficient power to drive a speaker even if it is amplified in the succeeding circuits. Further, even if the speaker is driven by such a signal, the human ear is not sensitive to the high order harmonic components.

As described above, substantially no lower order harmonic components or audio-frequency components will appear at the node 34, and yet extremely weak audio-frequency components are further attenuated when they are made to pass through the collector barrier capacitance. As a result, the level S_{off} of the leakage signal occurring at the output terminal 33 becomes very low, and the opening-closure ratio (S_{on}/S_{off}) is increased. Thus, one of the objects of the present invention can be accomplished. In the foregoing, description has been made of the switching device according to an embodiment of the present invention, and it has been found that such a device can satisfactorily operate when the circuit constants are selected as indicated in table 1.

TABLE 1

	Rectangular signal voltage of the generator 21 (peak value), 10V.
	Diode 32, 1S1473.
	Transistor 22, NPN silicon transistor 2SC458.
	Potential source $+V_3$, 12V.
	Potential source $+V_4$, 10V.
	Resistor 25, 20K Ω .
	Resistor 26, 80K Ω .
	Resistor 27, 400 Ω .
	Resistor 28, 50K Ω .
	Resistor 30, 63 Ω .
	Resistor 31, 3.2K Ω .
	Capacitor 29, 50 μ F.

In the circuit arrangement of FIG. 2 which has the circuit constants as indicated in table 1, the opening-closure ratio measured at a signal source frequency of 1 KHz was in a range of 80 to 90 dB. The signal level was measured with respect to the peak-to-peak value of the voltage waveform. From this, it will be appreciated that the circuit of FIG. 2 is advantageous over the circuit of FIG. 1 since with the latter circuit the opening-closure ratio is about 50 dB at best.

Referring now to FIG. 3, there is shown the device according to another embodiment of this invention, which is different from the device shown in FIG. 2 in that there is provided electronic switching means constituted by a common collector transistor circuit. However, these two devices are substantially similar to each other in respect of the basic operation. In FIG. 3, the collector electrode of a transistor 42 is grounded through a load resistor 47, and a signal source 41 is connected between the ground and a diode 52 connected at the node 54 with the base of the transistor. With the emitter electrode of the transistor is connected an envelope forming circuit 44 consisting of a resistor 48 and a capacitor 49 through an emitter resistor 51. A resistor 50 is connected between the node 55 and one terminal of a key switch 43 of which the other terminal is provided with a potential source $-V_5$. A bias resistor 45 is connected between the nodes 54 and 55. The transmission of the signal source 41 to the output terminal 53 is controlled by means of the key switch 43. With such a switching circuit, not only the desired "sustain" effect can be produced, but also a satisfactory opening-closure ratio can be obtained and the emitter junction breakdown trouble can be reduced.

By way of example, the circuit constants of the switching device were selected as indicated in table 2, and a satisfactory operation was performed.

TABLE 2

Rectangular wave signal source voltage, 10V.
 Diode 52, 1S1473.
 Transistor 42, NPN silicon transistor 2SC458.
 Resistor 45, 5K Ω .
 Resistor 47, 200 Ω .
 Resistor 48, 40K Ω .
 Resistor 50, 50 Ω .
 Capacitor 49, 50 μ F.
 Potential source $-V_s$, 12V.

It will be readily apparent to those skilled in the art that a unipolar transistor such as an insulated gate type field effect transistor may be used in place of a bipolar transistor such as the above NPN transistor, and also that instead of a single PN junction diode use may be made of a diode comprising a plurality of PN junctions connected in series with each other, a transistor, and another rectifying element in which conductive and nonconductive regions occur. Furthermore, in the foregoing the signal source has been described and illustrated by way of example as a source for providing a rectangular wave signal, it is also possible to use a sinusoidal signal source. Also, various modifications are possible without departing from the scope and spirit of the present invention defined in the appended claims.

I claim:

1. A switching device for electronic musical instrument, comprising an amplifier element having a control electrode and a pair of output electrodes, an output circuit from which is taken an output signal, said output circuit including said pair of output electrodes, a power source and a load impedance, an unsymmetrical type element connected with said control electrode, a signal source to supply an input signal to said control electrode through said unsymmetrical type element, said signal source being connected with said unsymmetrical type element, biasing means connected with said unsymmetrical and amplifier elements to impart a first and a second bias conditions thereto so that under the first bias condition said unsymmetrical type element is biased in the reverse direction and said amplifier element is so biased that its gain becomes substantially zero while under the second bias condition said unsymmetrical type element is biased in the forward direction and said amplifier element is so biased that its gain assumes a predetermined value, switch means for controlling said biasing means to thereby impart the first or second bias condition to the unsymmetrical type element or amplifier element in accordance with the opening or closing state of said switch means, and a time-constant circuit connected with said biasing means and switch means for delaying the switching of the bias condition for a predetermined period of time so that said second bias condition is gradually changed to the first bias condition when said switch means is switched from "on" to "off".

2. A switching device for electronic musical instrument, comprising a transistor having emitter, base and collector electrodes, an output circuit from which is taken an output signal, said output circuit including a load impedance, said emitter and collector electrodes and a d.c. power source, a rectifier element having two terminals and a rectifying junction, one of said two terminals being connected with the base

electrode of said transistor so that the conducting direction of said rectifying junction becomes the same as that of the emitter-base PN junction of said transistor, a signal source connected with the other terminal of said rectifier element to apply an input signal to said base electrode through said rectifier element, means for imparting a first and a second bias conditions to the connection point between said rectifier element and said base electrode and the emitter electrode of said transistor so that under the first bias condition said transistor is so biased that its gain becomes substantially zero and said rectifying junction is biased in the reverse direction while under the second bias condition said transistor is so biased that its gain assumes a predetermined value and said rectifying junction is biased in the forward direction, a switch connected between said emitter electrode and one electrode of said d.c. power source for controlling said biasing means, said switch being adapted to impart said first or second bias condition to both said connection point and said emitter electrode according to whether said switch is opened or closed, and a CR time-constant circuit connected with said biasing means and said switch for delaying the switching of the bias condition for a predetermined period of time so that said second bias condition is gradually changed to the first bias condition when said switch is switched from "on" to "off".

3. A switching device for electronic musical instrument, comprising a signal source, a transistor having emitter, base and collector electrodes, a PN junction diode connected between the signal source and the base electrode of said transistor in such a manner that the conducting direction thereof becomes the same as that of the emitter-base PN junction of said transistor, a first potential source having a predetermined potential relative to a reference potential point for operating said transistor, a first resistor connected between said first potential source and the collector electrode of said transistor, an output terminal connected with said collector electrode, a second resistor connecting the emitter and base electrodes with each other, a capacitor connected between the emitter electrode and the reference potential point, a key switch connected between the emitter electrode and the reference potential point, a second potential source having a predetermined potential relative to the reference potential point for imparting bias voltages to said diode and said transistor, the potential of said second potential source being selected to be higher than the peak value of the signal voltage, and a third resistor connected between said second potential source and said emitter electrode.

4. A switching device for electronic musical instrument, comprising a signal source, a transistor having emitter, base and collector electrodes, a first resistor connected between the collector electrode and a reference potential point, a PN junction diode connected between said signal source and the base electrode in such a manner that the conducting direction thereof becomes the same as that of the emitter-base PN junction of said transistor, a second resistor connected between the emitter and the base of said transistor, a potential source, a key switch connected between the potential source and the emitter electrode, a third resistor connected between the emitter electrode and the reference potential point, and a capacitor connected between the emitter electrode and the potential source.