United States Patent

[11] **3,617,598**

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[21] Appl. No. **14,070**
[22] Filed **Feb. 25, 1970**
[45] Patented **Nov. 2, 1971**
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[54] **SAWTOOTH TONE GENERATING AND KEYING CIRCUIT FOR AN ELECTRONIC MUSICAL INSTRUMENT**
16 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **84/1.01,** 84/1.11, 307/228, 328/36, 328/185, 331/111, 331/153
[51] **Int. Cl.** **G10h 5/10**
[50] **Field of Search** 84/1.01, 1.11, 1.13, 1.19, 1.24, 1.26; 307/228; 328/36, 185, 181; 331/111, 153

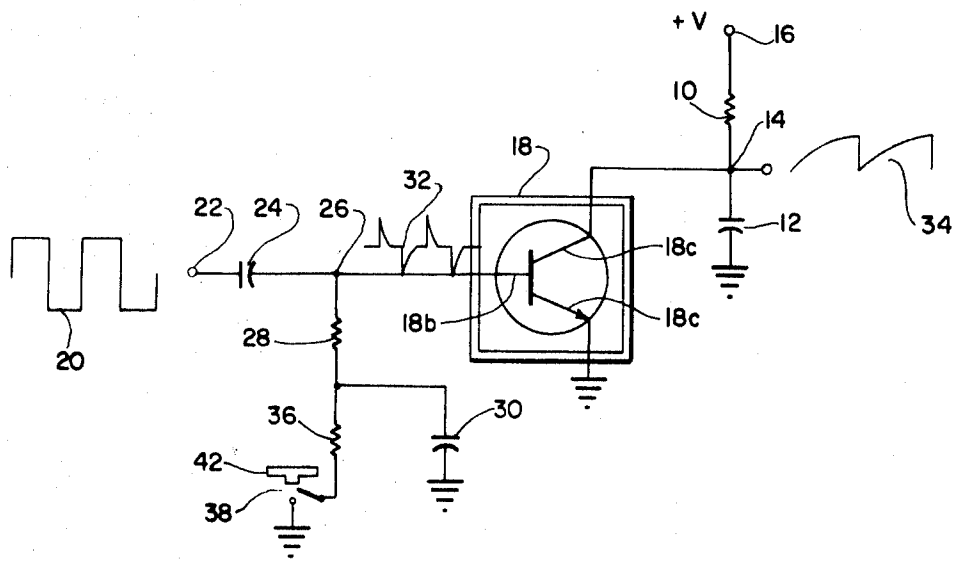
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ABSTRACT: A circuit is provided for generating an output signal having the characteristics of a natural musical tone by converting a square wave input signal into a sawtooth wave output signal. The circuit includes a unidirectional current device and a biasing circuit providing a gradually changing bias voltage to the unidirectional current device. The circuit thereby produces a sawtooth wave output signal of gradually increasing and diminishing magnitude. Circuit arrangements are also provided for combining the musical tones produced by a plurality of such circuits.



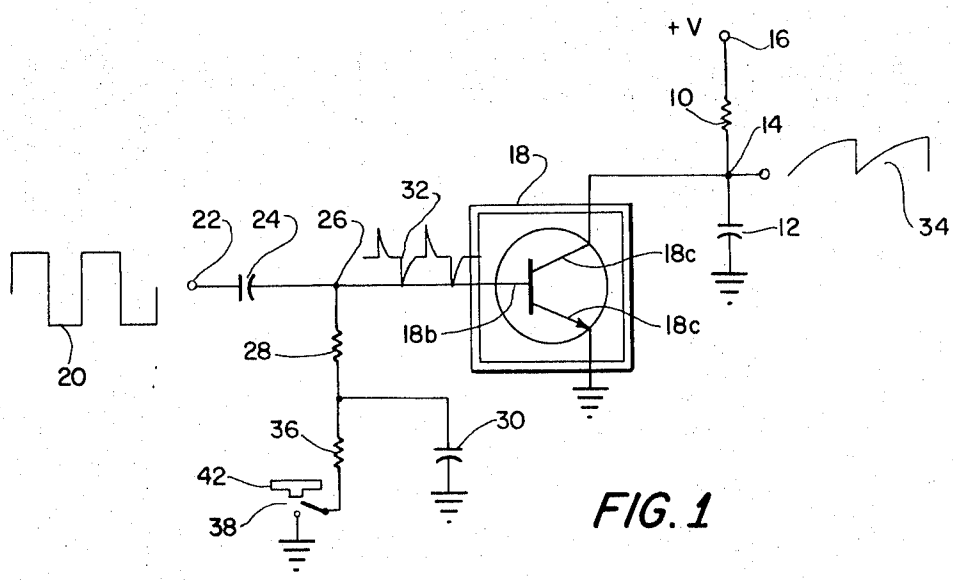


FIG. 1

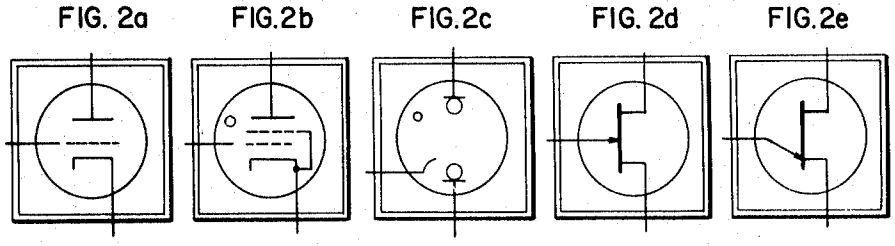


FIG. 2

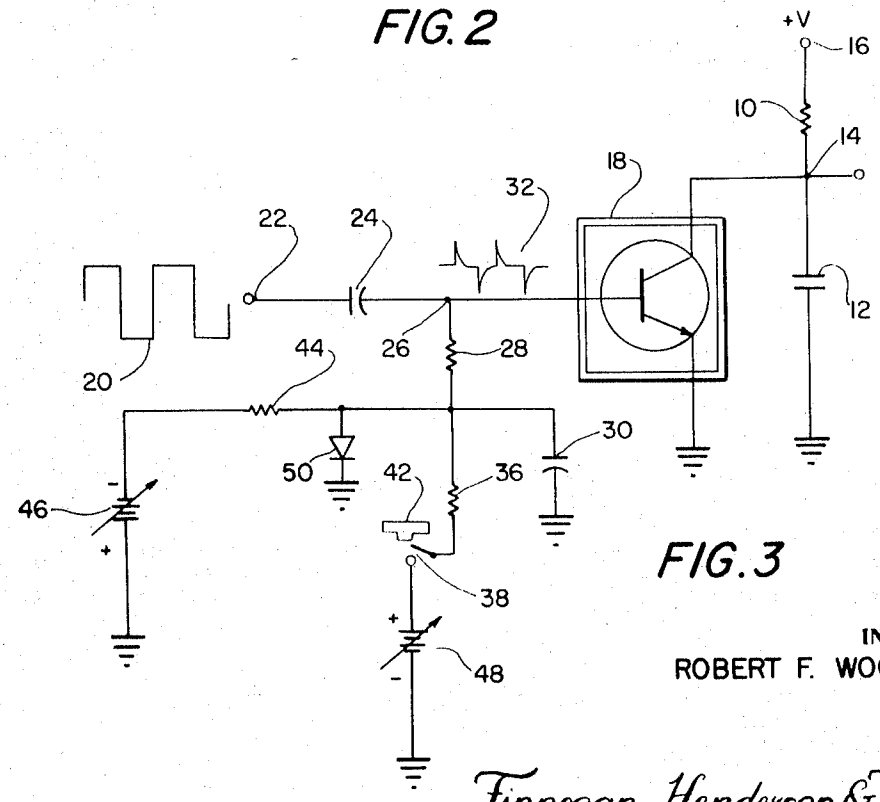


FIG. 3

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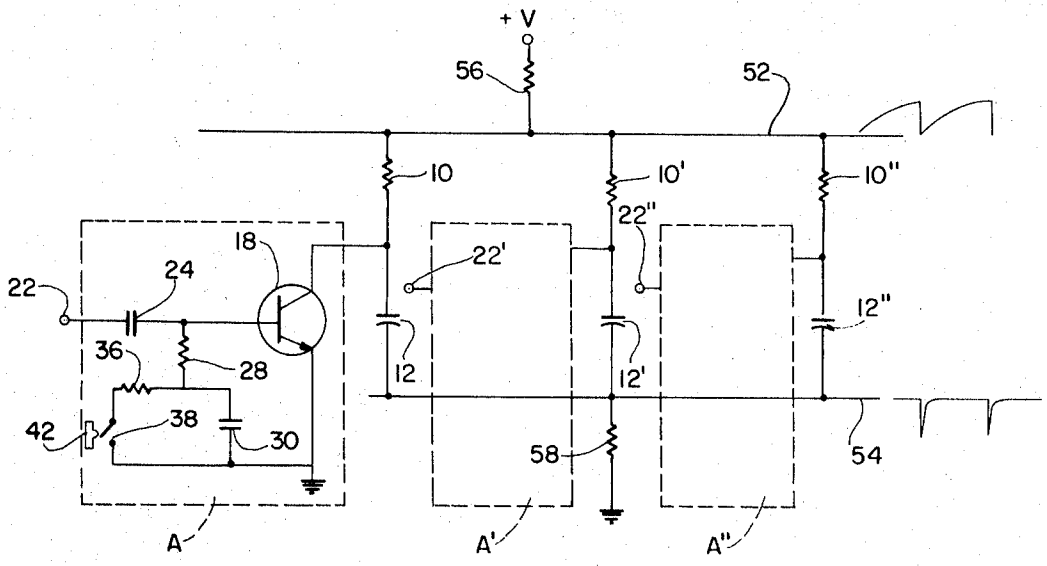


FIG. 4

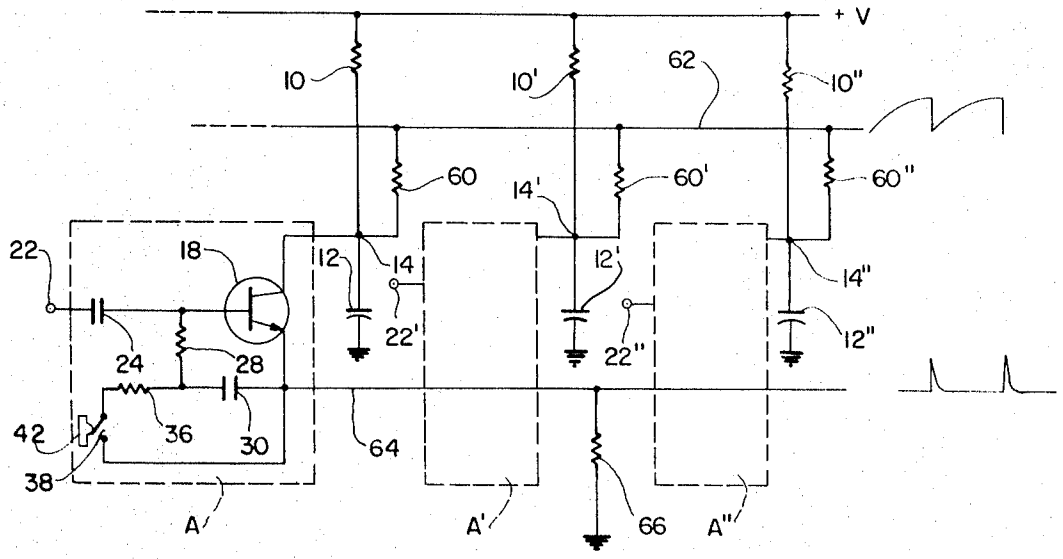


FIG. 5

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SAWTOOTH TONE GENERATING AND KEYING CIRCUIT FOR AN ELECTRONIC MUSICAL INSTRUMENT

The present invention relates to circuits for generating sawtooth wave output signals, and more particularly, to circuits for generating sawtooth wave output signals having the characteristics of natural musical tones.

In recent years, there has been an expanding interest in the field of electronic music. Electronic instruments, such as electronic organs, pianos, and harpsicords, have become increasingly popular. Instruments of this type have employed keying arrangements for turning on and turning off musical tones in response to the depression of playing keys.

Prior art circuits for generating electronic musical tones have generally utilized square wave generators, e.g. flip-flops, as a source of musical frequency. Since square waves do not contain the even-order harmonics of natural musical tones it has been necessary to provide circuitry for inserting the desired harmonics in the musical tones by converting square wave signals into sawtooth wave signals. In the prior art, the even-order harmonics of natural musical tones have been provided by converting square wave signals into sawtooth wave signals, or by combining square wave and sawtooth wave signals to produce a composite signal containing even-order harmonics.

Further, the prior art keying arrangements for electronic musical instruments have utilized electrical switches actuated by the depression of playing keys for selecting the musical tones to be played. In the prior art instruments, the musical quality of the tones has been limited by the abrupt manner in which the tones are turned on and off by the keying arrangements. In addition, the musical quality of the tone has been impaired by key clicks which are audible through the sound-reproducing system of the instrument when a musical tone is turned on or turned off.

These disadvantages of the prior art keying arrangements used in electronic musical instruments have been heretofore overcome by the use of variable resistance switches in the keying arrangements. Such variable resistance switches unfortunately require greater operating force and occupy more space than other types of electrical switches. When used in a keying arrangement for an electronic musical instrument, variable resistance switches thus limit the number of switches that can be actuated by a particular playing key, and the number of different musical frequencies that can be obtained by pressing that key.

In order for an electronic musical tone to have the characteristics of a natural musical tone, it is desirable that the electronic tone have a smooth and relatively fast turn-on rate, and a turnoff rate slower than the turn-on rate. Moreover, once a playing key has been depressed and released, the musical tone should diminish over a period of time that is not dependent on the motion of the playing key. The rates at which a musical tone obtained by operation of the variable resistance switch can be turned on and turned off are however dependent upon the speeds at which a playing key for operating the switch is depressed and released. Thus, smooth and uniform turn-on and turnoff rates are difficult to attain in instruments having variable resistance switches.

The tone-generating and keying circuit of the present invention operates generally on the principle of converting a square wave input signal into a sawtooth wave output signal having characteristics which are similar to a natural musical tone. In accordance with the present invention, a circuit for generating a sawtooth wave output signal for use in an electronic musical instrument contains an RC timing circuit consisting of a resistance and a timing capacitance connected in series and a source for applying a potential difference to the RC timing circuit to charge the timing capacitance.

The circuit also includes means for periodically discharging the timing capacitance to permit the potential difference from the source to recharge the timing capacitance. The voltage across the capacitance provides an output signal in the form of a sawtooth wave. In addition, the circuit includes means for gradually increasing and diminishing the magnitude of the sawtooth wave output signal to provide a natural musical tone. This means includes a biasing circuit which determines the turn-on and turnoff rates of the musical tone produced by the tone generating circuit.

In a preferred embodiment of the invention, the timing capacitance is periodically discharged by a transistor having its collector electrode connected to the capacitance for dissipating charge from the capacitance. A series of operating pulses are applied to the base electrode of the transistor to periodically drive the transistor into conduction and periodically discharge the timing capacitance. During the time between operating pulses the timing capacitance is recharged to provide a sawtooth wave output signal.

The preferred embodiment of the invention contains a biasing circuit for providing a bias voltage at the base electrode of the transistor. The biasing circuit determines the turn-on and turnoff rates of the tone generating circuit. It provides a gradually changing bias voltage at the base electrode to bias the transistor into a nonconducting state and gradually diminish the magnitude of the sawtooth wave output signal.

This invention is particularly useful in an electronic musical instrument from which it is desired to obtain an output signal having the characteristics of a natural musical tone. The circuit of the present invention provides a sawtooth wave output signal having turn-on and turnoff rates which are characteristic of the musical tone produced by a conventional, nonelectronic musical instrument.

An alternative embodiment of the present invention provides an arrangement for selectively varying the turnoff and turn-on rates of the musical tone produced by the tone generating circuit. With this arrangement, the musical tones produced by various musical instruments can be more readily imitated by adjusting circuit components which control the turn-on and turnoff rates of the output signal produced by the circuit.

The present invention also contemplates a circuit arrangement in which the musical tones produced by a plurality of tone generating circuits are combined. In this arrangement, the tone generating circuit of the present invention provides output signals in the form of sawtooth waves and spike pulses.

The accompanying drawings illustrate preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention.

Of the drawings:

FIG. 1 is a schematic diagram of a tone-generating circuit, including an RC timing circuit and a unidirectional current device, for generating a sawtooth wave output signal which operates in accordance with the principles of the present invention;

FIG. 2 illustrates a number of alternative electronic devices which can be substituted for the unidirectional current device included in the circuit of FIG. 1;

FIG. 3 illustrates an alternative embodiment of the tone-generating circuit of the present invention for producing a sawtooth wave output signal;

FIG. 4 illustrates a circuit arrangement for combining the output signals from a plurality of tone-generating circuits; and

FIG. 5 illustrates another circuit arrangement for combining the output signals from a plurality of tone-generating circuits.

FIG. 1 shows a circuit for generating a sawtooth wave output signal in accordance with the present invention. The circuit produces an output signal having the characteristics of a natural musical tone, and is particularly useful as a tone-generating circuit for electronic musical instruments.

In accordance with the invention the circuit includes an RC timing circuit. It also includes a source for applying a potential difference to the RC timing circuit to charge the timing capacitance. As embodied, the RC timing circuit consists of a resistance **10** (FIG. 1) and a timing capacitance **12** connected in series and having a common terminal **14**. Resistance **10** has a terminal **16** which is connected to a source (not shown) for

applying a potential difference to the RC timing circuit to charge timing capacitance 12 which is connected to ground.

In accordance with the invention the circuit also includes means for periodically discharging the timing capacitance to permit the potential difference from the source to recharge the timing capacitance. As embodied, this means includes a unidirectional current device having a control electrode for controlling the conduction of the unidirectional current device. In a preferred embodiment of the invention, as shown in FIG. 1, the unidirectional current device is a transistor 18 having a base electrode 18*b* for controlling the current conducted from collector electrode 18*c* to emitter electrode 18*e* of the transistor.

As shown in FIG. 1, collector electrode 18*c* of the transistor is connected to capacitance 12 at common terminal 14, and emitter electrode 18*e* of the transistor is connected to ground. Transistor 18 is used to dissipate charge from capacitance 12 when it is driven into a conducting state.

Further, in the preferred embodiment of the invention, means is provided for periodically applying operating pulses to the control electrode of the unidirectional current device to periodically drive the unidirectional current device into conduction and periodically discharge the timing capacitance. As embodied in the circuit, this means includes a source (not shown) for producing a square wave input signal as illustrated by waveform 20. The square wave input signal is applied to a first terminal 22 of an input capacitor 24 having a second terminal 26 connected to the base electrode of transistor 18. A resistance 28 is connected to terminal 26 of capacitor 24 and is also connected through a biasing capacitor 30 to ground. Capacitance 24 and resistance 28 provide a differentiating circuit for the square wave input signal applied to terminal 22.

As shown in FIG. 1, the differentiating circuit, i.e. capacitance 24 and resistance 28, produces a series of alternating positive and negative spike pulses at terminal 26 which are applied to the base electrode of transistor 18. The positive and negative spike pulses are illustrated as waveform 32 of FIG. 1.

The positive spike pulses of waveform 32 periodically drive transistor 18 into momentary conduction for a sufficient amount of time to discharge timing capacitance 12. During the time periods between positive spike pulses, the transistor is in a nonconducting state, and timing capacitance 12 is allowed to recharge. The resultant output signal at terminal 14 is s sawtooth wave signal, illustrated by waveform 34. The negative spike pulses of waveform 32 have the effect of applying a back-bias voltage to the base electrode of transistor 18, but since these negative spike pulses are applied to transistor 18 at a time when the transistor is in a nonconducting state, the back-bias voltages do not affect the conduction of the transistor.

The base-emitter junction of transistor 18 serves as a rectifier for the positive and negative spike pulses of waveform 32 so that no current flows through the junction during the negative spike pulses. Thus, biasing capacitor 30 is normally charged to a negative potential by the negative spike pulses.

In accordance with the invention, means is provided for gradually increasing and gradually diminishing the magnitude of the sawtooth wave output signal of the tone-generating circuit. This means provides gradual turn-on and turnoff rates for the musical tone produced by the tone-generating circuit. As embodied, this means comprises a biasing circuit for applying a bias voltage at the control electrode of the unidirectional current device. The biasing circuit includes resistance 28 and biasing capacitance 30, previously described. As shown in FIG. 1, biasing capacitance 30 is connected to the base electrode of transistor 18 through resistance 28 and, as described above, the biasing capacitance is normally charged to a negative potential by the negative spike pulses applied to the base electrode. This negative potential of biasing capacitance 30 results in a negative bias voltage at the base electrode of transistor 18 which normally maintains the transistor in a nonconducting state.

In addition, the biasing circuit includes means for discharging the biasing capacitance to remove the bias voltage from the control electrode of the unidirectional current device. As embodied, this means includes a resistance 36 and a normally open switch 38 connected in series with biasing capacitance 30. When normally open switch 38 is closed, the biasing capacitance is discharged through resistance 36 to remove the negative bias voltage from the base electrode of transistor 18.

The discharge of biasing capacitance 30 occurs gradually and permits the transistor to be driven periodically into conduction by the positive spike pulses of waveform 32. As a result, a sawtooth wave output signal of gradually increasing magnitude appears at terminal 14 of the tone generating circuit. When the biasing capacitance is completely discharged, the magnitude of the sawtooth wave output signal is at its maximum value.

The time required for the discharge of biasing capacitance 30 is determined by the values of the biasing capacitance and resistance 36. This time can be controlled by varying the values of the biasing capacitance and the resistance. In imitating natural musical tones it is desirable to select the values to provide a turn-on rate which is shorter than the turnoff rate of the musical tone produced.

Timing capacitance 12 is rapidly discharged each time transistor 18 is momentarily rendered conductive by the positive spike pulses of waveform 32. Thereafter, timing capacitance 12 is recharged by the potential difference applied to the RC timing circuit (i.e. resistance 10 and capacitance 12). As described above, the output signal of the tone-generating circuit which results from the periodic discharging and recharging of timing capacitance 12 appears at terminal 14 in the form of a sawtooth wave signal, as illustrated by waveform 34.

As long as normally open switch 38 is closed, transistor 18 is allowed to be driven periodically into conduction by the positive spike pulses applied to its base electrode, and the desired sawtooth wave output signal is produced at terminal 14. When switch 38 is opened, however, biasing capacitance 30 is gradually recharged through resistance 28 by the negative spike pulses of waveform 32, and the potential across the biasing capacitance is gradually returned to its normally negative value to render transistor 18 nonconducting.

As biasing capacitance 30 is gradually recharged to its normally negative potential, a gradually changing bias voltage is applied at the base electrode of the transistor to bias the transistor into a nonconducting state. During the recharging of biasing capacitance 30, the magnitude of the sawtooth wave output signal of waveform 34 is gradually diminished to provide a musical tone which, like musical tones produced by conventional musical instruments, slowly fades away.

When the circuit of the present invention is incorporated in an electronic musical instrument, normally open switch 38 is arranged to be actuated by a playing key 42 of the instrument. The circuit may be operated to produce a percussive musical tone by depressing and immediately releasing playing key 42 to momentarily close normally open switch 38. Biasing capacitance 30 is discharged by the momentary closure of switch 38 and then is gradually recharged by the negative spike pulses applied to the base electrode of transistor 18. The musical tone produced by the circuit, in this instance, has an initially large magnitude which gradually diminishes as biasing capacitance 30 is recharged to its normally negative potential.

Referring to FIG. 2, there are shown other examples of unidirectional current devices which can be substituted for transistor 18 of FIG. 1. These devices include a vacuum tube triode (FIG. 2*a*); a thyratron (FIG. 2*b*); a gas discharge lamp having a trigger electrode (FIG. 2*c*); a field effect transistor (FIG. 2*d*); and a unijunction transistor (FIG. 2*e*).

In the case where a vacuum tube triode (FIG. 2*a*) is used in the tone-generating circuit, the control grid of the triode is connected to terminal 26 of the circuit of FIG. 1 and the plate and cathode of the triode are connected to terminal 14 and ground, respectively. Similarly, when a thyratron (FIG. 2*b*) is

used in the circuit, the control grid of the thyratron is connected to terminal **26** (FIG. **1**) and the plate and cathode of the thyratron are connected to terminal **14** and ground, respectively.

When a gas discharge lamp (FIG. 2*c*) is used in the circuit its trigger electrode is connected to terminal **26** of the tone-generating circuit, and its remaining electrodes are connected to terminal **14** and to ground. In the case of a field effect transistor (FIG. 2*d*), the gate electrode of the transistor is connected to terminal **26** of the circuit and the drain and source electrodes are connected to terminal **14** and ground, respectively. Finally, when a unijunction transistor (FIG. 2*e*) is used in the tone-generating circuit, its emitter electrode is connected to terminal **26** of the circuit, its base number one electrode is connected to ground and its base number two electrode is connected to terminal **14**.

In the tone-generating circuit of the present invention, the values of the circuit components may be varied to produce different musical effects. When it is desired to reduce the turnoff time of the musical tone produced by the circuit, e.g. to imitate the musical tone produced by a pipe organ, the value of biasing capacitance **30** is decreased. The value of the biasing capacitance is increased if it is desired to produce a musical tone having a longer turnoff time, e.g. to provide chime or reverberation effects. The turn-on time of the musical tone can also be varied by changing the value of resistance **36**.

Referring to FIG. **3**, an alternative embodiment of the circuit of the present invention is shown. The components of the alternative embodiment which are identical to those of the presently preferred embodiment (FIG. **1**) have been designated by the same reference numerals used in the foregoing description of the invention.

As shown in FIG. **3**, the biasing circuit of the invention is provided with a resistance **44** and a variable voltage supply **46** for charging biasing capacitance **30** to a negative potential. The turnoff time of the musical tone produced by the circuit of the present invention can be shortened by adjusting variable voltage supply **46** to apply an increased negative voltage to resistance **44** and biasing capacitance **30**. In addition, the biasing circuit may be provided with a second variable voltage supply **48** which is connected to normally open switch **38**. The voltage of variable voltage supply **48** can be adjusted to vary the turn-on time of the musical tone produced by the circuit. For example, the turn-on time can be reduced by increasing the voltage supplied by variable voltage supply **48**. A diode **50** is connected between resistance **44** and ground to prevent biasing capacitance **30** from being charged to a positive voltage by variable voltage supply **48**.

In electronic musical instruments, it is often desirable to combine the musical tones produced from more than one tone-generating and keying circuit. FIG. **4** shows a first circuit arrangement for combining the musical tones produced by different tone-generating circuits.

As shown in FIG. **4**, a plurality of tone-generating and keying circuits A, A′, and A″ having RC timing circuits which consist of resistance **10**, **10′**, and **10″** and timing capacitances **12**, **12′**, and **12″** respectively, are connected by a first conductor **52** and a second conductor **54**. Resistances **10**, **10′**, and **10″** are connected to conductor **52** which, in turn, is connected to a source of potential (not shown) through a resistance **56**. Timing capacitances **12**, **12′**, and **12″** are connected to conductor **54** which, in turn, is connected to ground through a common resistance **58**.

Square wave input signals of different frequencies are applied to input terminals **22**, **22′**, and **22″** of the tone-generating and keying circuits. When the normally open switches of the tone-generating circuits are closed, the sawtooth wave output signals of the circuits are collected and combined on conductor **52**. Negative spike pulses appear at the terminals of timing capacitances **12**, **12′**, and **12″** which are connected to common resistance **58**, and conductor **54** collects the negative spike pulses appearing at these terminals.

In FIG. **5**, a second circuit arrangement for combining the sawtooth wave output signals of a plurality of tone-generating and keying circuits, A, A′, and A″ is shown. The tone-generating circuits include RC timing circuits consisting of resistances **10**, **10′**, and **10″** and timing capacitances **12**, **12′**, and **12″**. A set of resistances **60**, **60′**, and **60″** is connected to terminals **14**, **14′**, and **14″** of the RC timing circuits. Resistances **60**, **60′**, and **60″** are also connected to a first conductor **62** which collects and combines the sawtooth wave output signals of the tone-generating and keying circuits.

As shown in tone-generating circuit A of FIG. **5**, a second conductor **64** is connected to the emitter electrode of the transistor in the tone-generating circuit. Conductor **64** is connected to ground through a resistance **66**. The purpose of conductor **64** is to collect positive spike pulses which appear at the emitter electrodes of the transistors of tone-generating circuits A, A′, and A″.

Square wave input signals having different frequencies are applied to input terminals **22**, **22′**, and **22″** of tone-generating circuits A, A′, and A″ (FIG. **5**). When the normally open switches of the tone-generating circuits are closed, the circuits produce sawtooth wave output signals at terminals **14**, **14′**, and **14″** having frequencies which are the same as the frequencies of the square wave input signals. The sawtooth wave output signals of the tone-generating circuits are applied through resistances **60**, **60′**, and **60″** to conductor **62** which combines the signals into a composite output signal containing different frequencies. At the same time, positive spike pulses of different frequencies appear at the emitter terminals of the transistors of tone-generating circuits A, A′, and A″ which are connected to resistance **66**. These positive spike pulses are applied to conductor **64** which combines the pulses into a composite output signal.

In the operation of the circuits disclosed in FIGS. **4** and **5**, tone-generating circuits A, A′, and A″ can be operated separately or in combination to produce desired musical tones. In a first arrangement, the normally open switches of tone-generating circuits A, A′, and A″ may be arranged to be operated by separate playing keys of an electronic musical instrument. Alternatively, the normally open switches of the tone-generating circuits may be arranged to be simultaneously operated by a single playing key of the instrument. This alternative arrangement is particularly useful where it is desired to operate simultaneously a set of tone-generating circuits which produce output signals having harmonically related frequencies.

The tone-generating and keying circuit of the present invention produces a sawtooth wave output signal having the characteristics of a natural musical tone in that the turn-on and turnoff times of the resulting musical tone are similar to the turn-on and turnoff times of musical tones produced by conventional, nonelectronic musical instruments. As discussed above, the turn-on and turnoff times of the output signal can be regulated by varying the values of the circuit components to achieve different musical effects.

The invention in its broader aspects is not limited to the specific details shown and described, and modifications may be made in the details of the tone-generating and keying circuit without departing from the principles of the present invention.

What is claimed is:

1. A circuit for generating a sawtooth wave output signal for use in an electronic musical instrument, which comprises:

an RC timing circuit consisting of a resistance and a timing capacitance connected in series;

a source for applying a potential difference to said RC timing circuit to charge said timing capacitance;

means for periodically discharging said timing capacitance to permit the potential difference from said source to recharge said timing capacitance, the voltage across said timing capacitance providing an output signal in the form of a sawtooth wave;

said means for periodically discharging said timing capacitance including

a unidirectional current device connected to said timing capacitance and having a control electrode for controlling the conduction of said unidirectional current device, and

means for periodically applying operating pulses to said control electrode to periodically drive said unidirectional current device into conduction and to periodically discharge said timing capacitance; and

means for gradually increasing and diminishing the magnitude of the sawtooth wave output signal to provide a natural musical tone.

2. The circuit of claim 1, wherein

said unidirectional current device comprises a transistor having a collector electrode connected to said timing capacitance for dissipating charge from said timing capacitance and a base electrode: and

said operating pulses are applied to the base electrode of said transistor to periodically drive said transistor into conduction and periodically discharge said capacitance.

3. The circuit of claim 1 wherein the unidirectional current device comprises a vacuum tube triode having a plate connected to said timing capacitance and a grid for receiving said operating pulses.

4. The circuit of claim 1, wherein the unidirectional current devices comprises a thyratron having a plate connected to said timing capacitance and a control grid for receiving said operating pulses.

5. The circuit of claim 1, wherein the unidirectional current device comprises a gas discharge lamp connected to said timing capacitance and having a trigger electrode for receiving said operating pulses.

6. The circuit of claim 1, wherein the unidirectional current device comprises a field effect transistor having a drain electrode connected to said timing capacitance and a gate electrode for receiving said operating pulses.

7. The circuit of claim 1, wherein the unidirectional current device comprises a unijunction transistor having a base electrode connected to said timing capacitance and an emitter electrode for receiving said operating pulses.

8. The circuit of claim 2, wherein the means for gradually increasing and diminishing the magnitude of the sawtooth wave output signal includes:

a biasing circuit for applying a gradually changing bias voltage at the base electrode of said transistor to control the turn-on and turnoff rates of the sawtooth wave output signal.

9. The circuit of claim 4, wherein the biasing circuit includes:

a biasing capacitance connected to the base electrode of said transistor, said biasing capacitance being normally charged to a potential which maintains said transistor in a nonconducting state; and

means for discharging said biasing capacitance.

10. The circuit of claim 9, wherein the means for discharging the biasing capacitance includes:

a resistance and a normally open switch connected in series with said biasing capacitance; and

a playing key for operating said normally open switch to discharge said biasing capacitance through said resistance.

11. A circuit for generating a sawtooth wave output signal having the characteristics of a natural musical tone, which comprises:

a unidirectional current device having a collector electrode, an emitter electrode, and a base electrode for controlling the current conducted from said collector electrode to said emitter electrode;

an RC timing circuit consisting of a resistance and a timing capacitance connected in series and having their common terminal connected to the collector electrode of said unidirectional current device;

a source for applying a potential difference to said RC timing circuit to charge said timing capacitance;

means for periodically applying operating pulses to the base electrode of said unidirectional current device; and

a biasing circuit for applying a bias voltage of the base electrode of said unidirectional current device which normally maintains said unidirectional current device in a nonconducting state;

said biasing circuit including (1) means for removing the bias voltage from the base electrode of said unidirectional current device to permit said unidirectional current device to be driven periodically into conduction by the operating pulses applied to the base electrode, and to permit said timing capacitance to be periodically discharged through said current device to provide a sawtooth wave output signal, and (2) means for gradually returning the bias voltage to its normal level to render said current device nonconducting and thereby gradually diminish the magnitude of the sawtooth wave output signal.

12. The circuit of claim 11, wherein the biasing circuit includes:

a biasing capacitance connected to the base electrode of said unidirectional current device, said biasing capacitance being normally charged to a potential which maintains said unidirectional current device in a nonconducting state;

a normally open switch connected in series with said biasing capacitance for discharging said biasing capacitance when it is closed to permit said current device to be periodically driven into conduction by the generating pulses applied to the base electrode; and

means for recharging said biasing capacitance when said switch is in its normally open position to gradually return the potential across said biasing capacitance to its normal level to render said current device nonconduction.

13. The circuit of claim 12 which includes:

a playing key for operating said normally open switch.

14. A circuit for use in an electronic musical instrument, which comprises:

a plurality of tone-generating circuits having RC timing circuits for producing sawtooth wave output signals of different musical frequencies;

a first conductor connected to the resistances of said RC timing circuits for collecting the sawtooth wave output signals produced by said tone-generating circuits;

a common resistance; and

a second conductor for connecting said common resistance to terminals of the capacitances of said RC timing circuits and for collecting spike pulses which appear at the terminals of the capacitances connected to said common resistance.

15. A circuit for use in an electronic musical instrument, which comprises:

a plurality of tone-generating circuits for producing sawtooth wave output signals of different musical frequencies, each tone-generating circuit comprising

an RC timing circuit consisting of a resistance and a timing capacitance connected in series,

a source for applying a potential difference to said RC timing circuit to charge said timing capacitance, means for periodically discharging said timing capacitance to permit the potential difference from said source to recharge said timing capacitance, the voltage across said timing capacitance providing an output signal in the form of a sawtooth wave,

said means for periodically discharging said timing capacitance including a transistor having its collector electrode connected to said timing capacitance for dissipating charge from said timing capacitance and means for applying operating pulses to the base electrode of said transistor to periodically drive said transistor into conduction and periodically discharge said capacitance, and

means for gradually increasing and diminishing the magnitude of the sawtooth wave output signal to provide a natural musical tone;

a plurality of resistances connected to the capacitances of the RC timing circuits of said tone-generating circuits;

a first conductor connected to said plurality of resistances for collecting the sawtooth wave output signals produced by said tone-generating circuits; and

a second conductor connected to the emitter electrodes of the transistors of said tone-generating circuits for collecting spike pulses which appear at the emitter electrodes of said transistors.

16. The circuit of claim 15, which includes:

a common resistance connected to said second conductor.

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