

- [54] **MUSICAL INSTRUMENT HAVING DC-KEYING CIRCUIT**
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- [22] Filed: **April 30, 1971**
- [21] Appl. No.: **138,880**
- [52] U.S. Cl. **84/1.13, 84/1.22, 84/1.25, 84/1.26**
- [51] Int. Cl. **G10h 1/04**
- [58] Field of Search **84/1.01, 1.11, 1.13, 1.19, 84/1.25, 1.26, 1.12, 1.21, 1.22**

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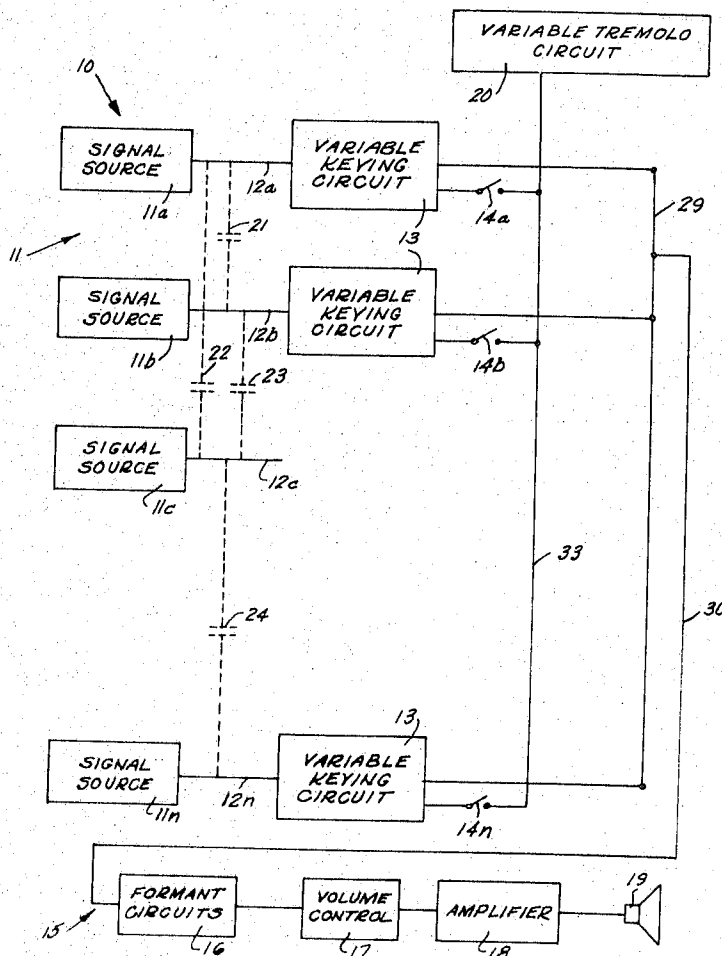
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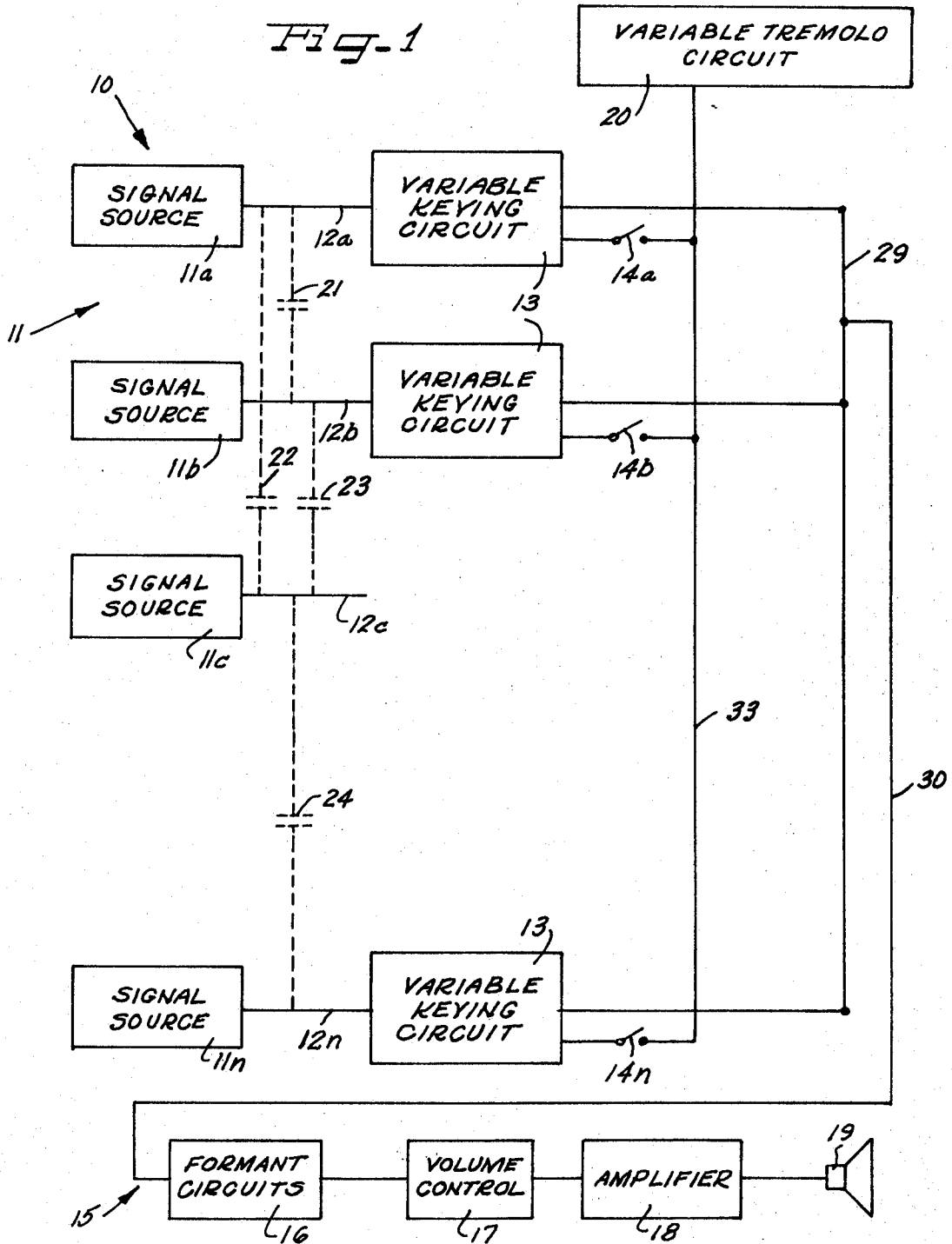
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[57] **ABSTRACT**

A musical instrument, such as an electronic organ, includes normally constantly running tone-signal sources which are coupled by key-operated switches to a transducer for converting the tone-signals into audible sounds by means of a DC-keying potential. The waveform of the tone signal comprises pulses which are modulated in shape by the DC-keying circuit as follows: at the onset or attack of the tone, the amplitudes of successive pulses are unidirectionally increased and the duration of said successive pulses are simultaneously unidirectionally decreased from a predetermined duration or duty cycle to a substantially shorter duration or duty cycle, while the reverse takes place at the decay of the tone. There is no modulation of frequency. By this circuit, the harmonic content of the tone-signal is varied in such a manner as to electronically closely simulate certain voices as brass, in a particularly realistic manner.

13 Claims, 5 Drawing Figures





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Fig-3

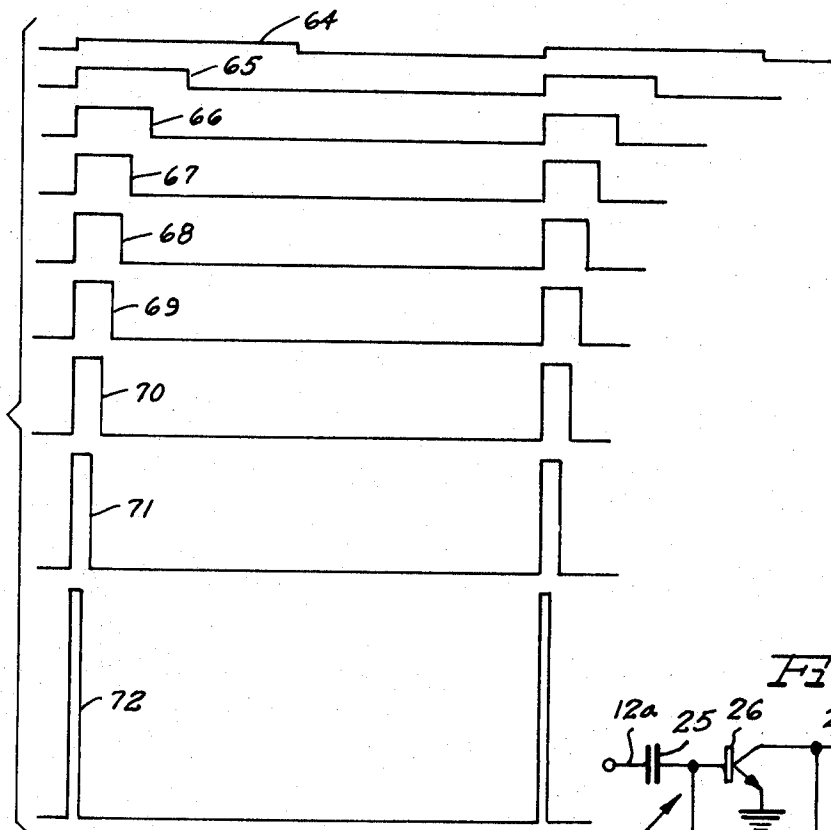


Fig-2

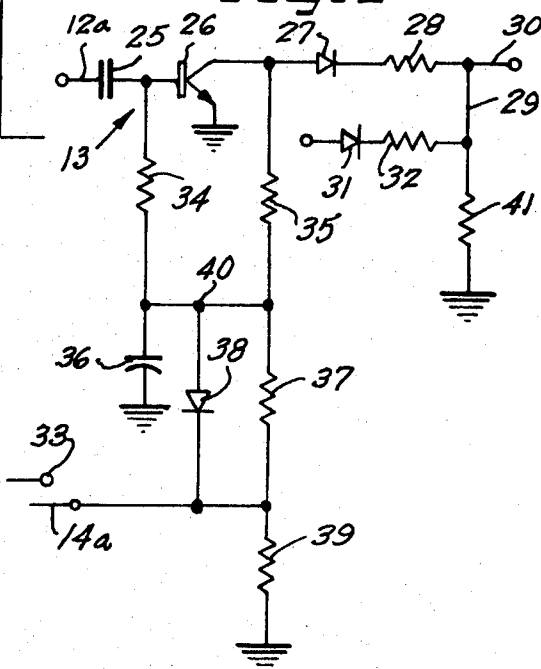
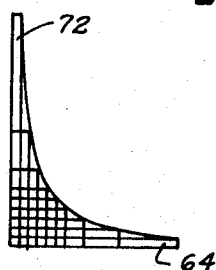


Fig-4



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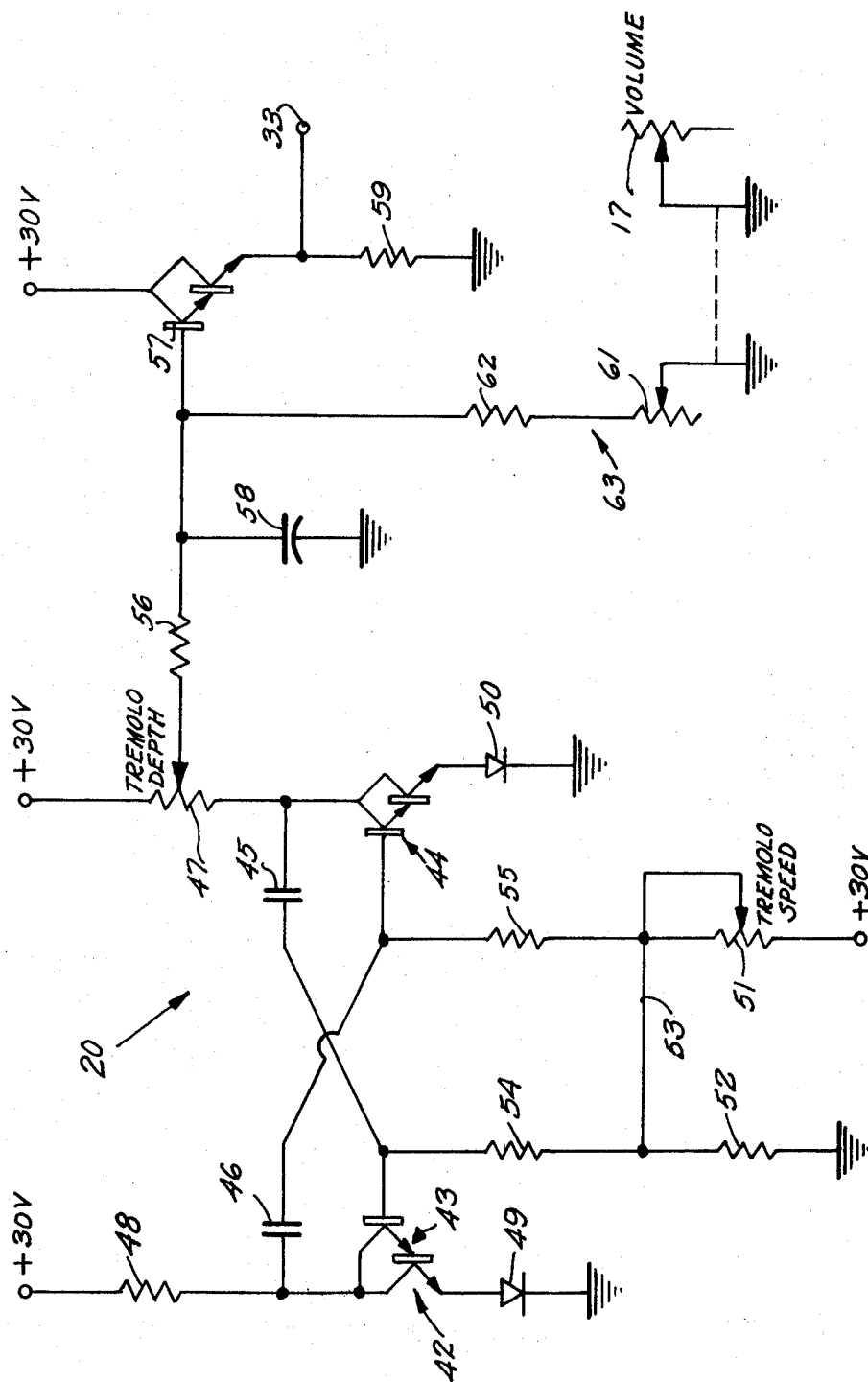
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FIG-5



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MUSICAL INSTRUMENT HAVING DC-KEYING CIRCUIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention deals with an electronic organ, and more particularly to a DC-keying circuit employed therein by which the initial tone-signal pulses are unidirectionally inversely modulated in duration and amplitude so that the harmonic content of the tone-signal is initially transiently varied.

2. Prior Art

In the known electronic organs, it is customary to provide tone signal sources under the control of keying means, such tone signals being processed by formant or filtering and/or combining circuits such that the initial wave form is thereby altered to provide a resulting wave form which contains the fundamental and the appropriate harmonics in appropriate relationship so as to simulate a great variety of organ voices. Examples of these include trumpet, tuba and bassoon. Common to these voices is the fact that each is designed to simulate a wind instrument where the onset or attack of the tone is produced by appropriate lip action of the musician. Such onset or attack, as well as decay have not previously been accurately simulated electronically and therefore these organ voices have lacked realism. Thus there has been a noticeable difference between the tone of an electronic organ that is being played with the trumpet stop or voice selected, and an actual trumpet. This difference has been particularly noted in the instance of certain electronic organs, i.e., continuously running tone signal sources that begin with a square wave tone-signal. Further, when a typical wind instrument is played, the harmonic content of the tone-signal will vary as a function of the loudness of the tone.

SUMMARY OF THE INVENTION

In accordance with the present invention, the attack and/or the decay can not only be controlled in the usual sort of way, but also the harmonic content of the tone-signal can be progressively altered during such attack and/or decay. When this is done to a proper extent, the tones of wind instruments such as brass instruments, reed instruments and double reed instruments are closely simulated. For these voices, the attack should begin with a strong fundamental that is low in harmonics, and as the attack progresses, the fundamental should become weaker in amplitude and the harmonic content should increase, the power level remaining substantially constant or increasing slightly. Further, if one were to reverse a diode in the circuit, the reverse of the foregoing would take place so as to simulate the attack and decay of a piano.

Accordingly, it is an object of the present invention to provide a musical instrument employing DC-keying by which the harmonic content of a tone-signal is transiently altered during the attack and/or decay of the tone.

A further object of the present invention is to provide a musical instrument of the electronic organ type having circuitry for simulating brass and reed wind instruments, piano, and/or organ voices such as diapason, kinura and Bach trumpets.

Many other advantages, features and additional objects of the present invention will become manifest to

those versed in the art upon making reference to the detailed description and the accompanying sheets of drawings in which a preferred structural embodiment incorporating the principles of the present invention is shown by way of illustrative example.

ON THE DRAWINGS

FIG. 1 is a block diagram of a musical instrument such as an electronic organ constructed in accordance with the present invention;

FIG. 2 is a circuit diagram of the means by which the DC-keying potential is varied for modulating the duration of each tone-signal pulse during the attack and/or decay of the tone;

FIG. 3 is a wave-form diagram showing the operation of the circuit of FIG. 2;

FIG. 4 is a composite diagram of the several wave forms of FIG. 3; and

FIG. 5 is a circuit diagram of a tremolo circuit shown in FIG. 1.

AS SHOWN ON THE DRAWINGS

The principles of this invention are particularly useful when embodied in a musical instrument such as an electronic organ shown in block diagram in FIG. 1 in simplified form. The musical instrument 10 includes a series of tone-signal sources 11 composed of individual signal sources 11a, 11b, 11c, - - - 11n. The actual number corresponds to the size of the instrument and thus typically includes 44 or 61 such sources. The signal sources 11 are the type that when the organ is energized, the signal sources 11 are constantly "on". Further, the signal sources produce tone-signals that have a wave form that includes a steep voltage-changing portion, for example a square wave or a saw tooth wave as distinguished from a sine wave or a triangular wave. The term "steep" means a wave form that has a portion of which is substantially vertical.

The signal sources 11 are connected by a cable of conductors 12a, 12b, 12c, - - - 12n to a series of variable keying circuits or modulation means, each identified by the reference numeral 13. A series of key-operated switches 14a, 14b, - - - 14n are connected to provide a DC-keying potential to the individual keying circuits 13 in response to actuation of one of the individual key-switches such as 14a. Actuation of a key-operated switch such as 14a couples the associated tone-signal source 11a to converting means generally indicated as 15. The converting means 15 includes conventional formant circuits 16 by which the tone-signal is appropriately shaped, and all of which are under the subsequent control of a volume control 17 normally positioned by an expression shoe (not shown), the output of which is directed to an audio amplifier 18 and one or more speakers 19. In this embodiment, the DC-keying potential for the several key-operated switches 14a, 14b, etc., is provided from a tremolo oscillator or variable tremolo circuit 20 described below.

As stated, the individual conductors 12a, 12b, etc. jointly comprise a cable and the conductors 12a, 12b, etc. individually interconnect the various tone-signal sources 11a, 11b, etc. with the various modulation means or variable keying circuits 13. The individual conductors 12a, 12b, are capacitively coupled to each other by virtue of the fact that the conductors lie in

close proximity to one another and jointly form a cable. The input impedance of the various variable keying circuits or modulation means 13 is relatively high, and therefore it is not necessary to provide individual capacitors between the various conductors 12a, 12b, etc., but the mutual capacitance between such conductors is sufficient for purposes of the present invention. Thus there is a capacitance between the conductor 12a and the conductor 12b identified in broken lines as a capacitor 21, a capacitance between the conductor 12a and the conductor 12c identified as a capacitance 22, a capacitance 23 and a capacitance 24 representing other capacitances between conductors. In fact, assuming that there are 61 conductors, there are 60 different mutual capacitances that any one conductor has with respect to the others in the cable. If it should be necessary to separate the conductors of the cable, small capacitors could be used instead of the mutual capacitance that is obtained from the cable. The effect of these capacitances is set forth in connection with the description of the operation of the invention.

The variable keying circuit or modulation means 13 is constructed as shown in FIG. 2, the connections being those for only one of the key-operated switches. This circuitry is repeated for each of the various variable keyed circuits or modulation means 13. The cable conductor 12a is connected to a capacitor 25 which is connected to the base of a transistor 26 of the NPN type. The emitter of the transistor 26 is connected to a voltage reference such as ground, while its collector is preferably connected through an isolation diode 27 and the coupling resistor 28 to a collector bus 29, the collector bus 29 being connected by a lead 30 to the converting means 15. The other variable keying circuits or modulation means are similarly connected to the various cable conductors and key-operated switches and their outputs are similarly connected through isolation means such as other diodes 31 and isolation resistors 32, only one of which is illustrated, the connection being to the collector bus 29.

The DC-keying potential appears on a keying bus 33 which is connected to all of the key-operated switches 14. The varying or modulation means 13, in addition to the capacitor 25 and the transistor 26 includes a pair of resistors 34, 35. The resistor 34 is connected at one end to the base of the transistor 26, while the resistor 35 is connected at one end to the collector of the transistor 26. The other ends of the transistors 34, 35 are connected together and to the key-operated switch 14a. The connection to the switch 14a is through means for controlling the attack and the decay of the tone-signal, and such means includes a capacitor 36 connected between ground and the common ends of the resistors 34, 35, a charging circuit that includes a resistor 37 connected between the key-operated switch 14a and the capacitor 36, and a discharge circuit comprising a diode 38 connected across the resistor 37. A further resistor 39 provides a reference for the DC-keying potential, and also forms a part of the discharge circuit.

When the key-operated switch 14a is closed, dc-keying potential is applied through the resistor 37 to charge the capacitor 36, such keying potential also appearing at the point 40 on the varying or modulation means 13. The rate of attack is thus determined by the size of the resistor 37 and the capacitor 36. The resistor

39 is relatively small so that when the key switch is opened, the capacitor 36 rapidly discharges through the diode 38 and the resistor 39. It is to be understood that these elements may have their size varied to provide any selected rate of attack and/or decay as may be desired. Thus, as illustrated, the circuit provides a relatively slow attack and fast decay. With the diode 38 connected reversely from that shown, a relatively fast attack and slow decay is similarly provided, as would be the case for a piano voice.

A resistor 41 provides a voltage reference for the collector bus 29.

The variable tremolo circuit 20 is shown in detail in FIG. 5 and includes a multivibrator generally indicated at 42 and which includes a pair of Darlington transistors 43, 44 each having a base connected through a capacitor 45, 46 to the collector of the other transistor 44, 43 respectively and through a resistor 47, 48 to its source of DC-potential. The emitters of the transistors 43, 44 are respectively connected through a pair of diodes 49, 50 to ground. A source of DC-voltage is connected through a variable resistor 51 and a further resistor 52 that have a common point 53 therebetween. The wiper of the variable resistor 51 is connected to such common point, whereby the variable resistor 51 and the resistor 52 jointly serve as a voltage divider with the common point 53 connected to one end of each of a pair of resistors 54, 55, the other ends of which are respectively connected to the base of the transistors 43, 44.

The multivibrator 42 oscillates at a speed which is controlled by the position of the wiper of the variable resistor 51, and the magnitude or depth of the tremolo is controlled by the position of the potentiometer 47 which is a voltage divider. When the wiper of the potentiometer 47 is at the upper end of the illustrated potentiometer 47, DC-potential is directly sensed and only direct current appears on the bus 33, and at the lowest point, a maximum depth of tremolo is obtained. The signal from the multivibrator is basically a square wave and this signal passes superimposed on a DC-signal or reference through a resistor 56 to the base of a Darlington transistor 57. A capacitor 58 is connected to one end of the resistor 56 and which thereby filters the signal to make the superimposed part of the wave form basically triangular. The collector of the transistor 57 is connected to a source of DC-potential, and the emitter is connected to a voltage reference resistor 59 and to the keying bus 33. In this manner, the transistor 57 is connected as an emitter follower to provide the DC-keying potential on the bus 33, which in this embodiment has the optional feature of enabling the selection of the ratio of DC-keying potential mixed with tremolo signal. No matter what this setting is, there is always a DC-keying potential on the bus 33 which cannot pass through zero volts.

The instrument has a volume control, manually under the control of an expression shoe, the same being partially illustrated at 17 as a potentiometer. Ganged to the potentiometer of the volume control is a second potentiometer 61 which is connected in series with a resistor 62 which jointly comprise a voltage divider generally indicated at 63. By this arrangement, the louder the volume control of the organ is set, the higher the DC-keying potential will be, whether it is subject to a tremolo signal or not.

With reference to FIG. 2, a tone-signal is always present at the conductor 12a and is normally blocked by the transistor 26. After the keyswitch 14a has been closed, voltage builds up in the capacitor 36. Because of the capacitance of the capacitor 25 and the resistance of the resistor 34, which have values that are approximately selected in view of the frequency of such tone-signal, the transistor 26 does not serve as a gate for the entire signal, but at the outset, the duty cycle or the percentage of a pulse that is conducted represents a pulse width which is less than the full duration of the pulse. As the voltage on the capacitor 36 continues to build up, the wave form at the collector of the transistor 26 continues to modulate in that it simultaneously increases in amplitude and decreases in duty cycle or duration exponentially. These inverse changes are smooth, but they pass smoothly through a number of wave forms that have been illustrated in FIG. 3. The uppermost wave form 64 is rich in the fundamental frequency and is low in harmonics. The wave forms 65-71 are during this unidirectional modulation progressively weaker in the fundamental and stronger in harmonics until the wave form 72 is reached which is the weakest in the fundamental and the strongest in the harmonics. The frequency has not been altered and therefore the pitch remains the same. Moreover, the area under the pulse is almost constant, having only a slight increase, and therefore the power level is substantially constant. FIG. 4 shows the wave forms 64-72 superimposed on one another. When the pulse 72 precedes the pulse 64, with time running from left to right, the illustrated superimposition represents the modulation occurring at the decay of a tone. When the pulse 64 precedes the pulse 62, with time running from right to left, the illustrated superimposition represents the modulation of the tone pulses at the onset of a tone. The shape of the resulting curve can be altered if desired by appropriate change of the values of the components 25, 34 and 35 and the voltage. When the key-operated switch 14a is released or opened, the diode 38 enables a rather rapid discharge of the capacitor 36 and thus has a rather rapid decay. Thus with proper selection of values, this circuit can be utilized to provide a selected rate of attack and a selected rate of decay. As explained, there is thus provided a circuit for unidirectionally simultaneously modulating the duration and amplitude of each tone signal pulse by varying the DC-keying potential without altering the tone signal frequency, the modulation of duration being an inverse function of the modulation of amplitude. A unidirectional modulation of amplitude at the onset of a tone is always from a lesser DC-keying potential to a higher DC-keying potential, and at the decay of a tone is always from a higher DC-keying potential to a lower DC-keying potential. One edge of the various tone signal pulses such as the leading edge is always stationary and unidirectional modulating of the duration is accomplished by having the other, such as the trailing edge varying. The trailing edge moves toward the leading edge at the onset of a tone to reduce the duration of successive tone-signal pulses, and the trailing edge moves away from the leading edge at the decay of a tone to provide increased duration of tone-signal pulses. Thus in such modulation, the increase of one of the parameters of duration and amplitude is accompanied by a decrease of the other of such parameters.

The longer that the cable of conductors 12a, 12b, etc., is, and the thinner that the insulation around each conductor is, the greater the capacitive coupling will be between the various conductors. Thus when only the key-operated switch 14a is closed, the conductor 12a will also carry some capacitatively coupled tone-signals from each of the sources 11b, 11c, - - - 11n. As explained further below, the signal at the onset of the tone is quite rich in various frequencies, and the first transient effect is thus the simulation of the musician's breath or a simulation of wind that accompanies the production of a tone at its onset. A typical length for the cable of conductors 12a, 12b, etc., is four feet, and it is preferred that the conductors be twisted in the cable for ensuring uniformity of mutual capacitive coupling.

The DC-potential on the keying bus 33 determines the amount of duty cycle, namely the pulse duration or width. The dc-potential on the keying bus 33 may be modulated by the tremolo signal, the average DC-potential being lower as tremolo depth increases. The DC-potential on the bus 33 can also be fixably lowered by the position of the voltage divider 63 that is ganged with the volume control 17. The louder that the volume control is set, the lesser the duty cycle or duration becomes and hence the more enriched in harmonics the keyed tone-signal becomes.

The keying circuitry of this invention can thus be used in association with voices where it is desired to electrically vary the harmonic content of an electrical tone-signal during the onset or during the decay of a tone. This is thus done by varying the duty cycle as a function of the attack and the decay. During the attack, there is an exponential buildup of potential in the capacitor 36, and at the same time, the same potential builds up on the collector of the transistor 26.

The transistor 26 has been illustrated as being of the NPN type, and with such type of transistor, the tone-signal source must have a sharp negative going pulse. If a transistor of the PNP type is employed in place of the transistor 26, then the tone-signal wave form must have a sharp or steep positive going pulse.

Using values given later herein, it takes about 80 milliseconds to charge the capacitor 36 to a voltage of about 20 volts. During the elapse of the 80 milliseconds, the duty cycle changes so that the time-to-amplitude ratio begins at about 5 or 6 to 1, and at the end of the 80 milliseconds, that ratio has changed to about 1 to 6 or 7 in amplitude. Thus the duty cycle decreases and causes the amplitude to increase and hence the harmonics to increase.

When the capacitor 25 is discharged by the action of the steep portion of a pulse from a signal source 11, it holds a negative potential. Therefore, the charge on the capacitor 36 gradually charges the capacitor 25 through the resistor 34, and builds up to a potential of about 0.6 volts at the base of the transistor 26.

In one test, I have observed that as the amplitude changed from 1 to 6½ units, the power level changed from about 4½ power units to about 6 units.

Because of the voltage divider 63, when the instrument is played softly, the harmonics tend to drop out, and when the instrument is played loudly, employing substantially full DC-keying potential, then the harmonics are added, simulating the presence of added harmonics when a wind instrument is blown harder.

Breath or wind simulation is obtained upon closure of the key switch 14a as the initially high input impedance of the transistor 26 serves to amplify the tone signals that are present because of leakage or capacitative coupling from the non-keyed notes. As the gate gradually opens, such coupling is gradually decreased as the input impedance decreases. But with pulse width and amplitude modulation, there is produced a change in harmonic content, effected by change in duty cycle, namely on-time as compared to off-time. With a square wave input at the transistor 26 and with a 50 percent duty cycle, square waves appear at the collector, which have only odd harmonics, and which constitutes a clarinet tone. As the off-time is lessened from 50 percent to less, even harmonics appear and eventually become predominant.

The following are the sizes of the various capacitors and resistors:

CAPACITORS

25: for the 44 notes from F (87.3) to C (1046.5), for the

lowest 6 notes	500 uuf
next 6 notes	360 uuf
next 6 notes	250 uuf
next 12 notes	200 uuf
next 6 notes	150 uuf
top 8 notes	100 uuf
36	1 mfd.
45	0.1 mfd.
46	0.1 mfd.
58	2 mfd

RESISTORS

28	56 K
32	56 K
34	680 K
35	68 K
37	68 K
39	10 K
41	3.3 K
47	5 K
48	4.7 K
51	25 K
52	10 K
54	1 M
55	1 M
56	15 K
59	4.7 K
61	50 K
62	2.7 K

Although various minor modifications might be suggested by those versed in the art, it should be understood that I wish to embody within the scope of the patent warranted hereon, all such embodiments as reasonably and properly come within the scope of my contribution to the art.

I claim as my invention:

1. A musical instrument comprising:

- a. a series of tone-signal sources normally constantly in operation and having a wave form including a steep voltage-changing portion;
- b. means for converting tone-signals into audible sound;
- c. a source of DC-keying potential;
- d. a series of key-operated switches connected to said source of DC-keying potential; and
- e. a modulating DC-keying circuit means controlled by said key-operated switches and connected between said tone-signal sources and said converting means for coupling said tone-signal sources to said converting means while also unidirectionally simultaneously modulating the duration and am-

plitude of each tone signal pulse by varying said DC-keying potential without altering the tone signal frequency, the modulation of duration being an inverse function of the modulation of amplitude.

2. A musical instrument according to claim 1 including conductors which interconnect said tone-signal sources with said modulating means, said conductors having a capacitative coupling with each other.

3. A musical instrument according to claim 2 in which said conductors comprise a cable with said conductors disposed in proximity to each other whereby said capacitative coupling is established by the mutual capacitance between conductors.

4. A musical instrument according to claim 1 in which each of said modulating means includes:

- a. a transistor having a base, a collector coupled to said converting means, and an emitter connected to a voltage potential reference;
- b. one of said key-operated switches having a resistive coupling with said base and with said collector for applying the DC-keying potential thereto; and
- c. a capacitor coupling said base to one of said tone-signal sources.

5. A musical instrument according to claim 4 including isolation means by which said collector of each of a plurality of said modulating means are connected together as a collector bus, said collector bus having a coupling with said converting means.

6. A musical instrument according to claim 1 including means for each of said switches for controlling the rates of attack and decay, said controlling means respectively connecting each of said switches to each of said modulating means.

7. A musical instrument according to claim 6 in which said controlling means comprises:

- a. a capacitor connected to said modulating means;
- b. a charging circuit between the key-operated switch and said capacitor; and
- c. a discharge circuit connected to said capacitor.

8. A musical instrument according to claim 7 in which said charging circuit has an impedance several times greater than that of said discharge circuit, whereby a brass instrument tone is simulated.

9. A musical instrument according to claim 1 including a tremolo oscillator connected to said source of DC-keying potential to cyclically vary the magnitude of said DC-keying potential by superimposing a tremolo signal thereon.

10. A musical instrument according to claim 9 having a selectively positionable voltage divider connected to said tremolo oscillator and to said source of DC-keying potential to select the ratio of the DC-keying potential and said tremolo signal.

11. A musical instrument according to claim 1 having a selectively positionable voltage divider connected with said source of DC-keying potential to determine said DC-keying potential.

12. A musical instrument according to claim 11 having a selectively positionable volume control connected to said converting means, said volume control and said voltage divider having a mechanical connection with each other for joint operation, and so connected electrically that the dc-keying potential will be increased as volume is increased.

13. A musical instrument according to claim 1 in which the modulated tone signal pulses are rectangular.

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