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[21] Appl. No. 857,806
[22] Filed Sept. 15, 1969
[45] Patented Aug. 31, 1971

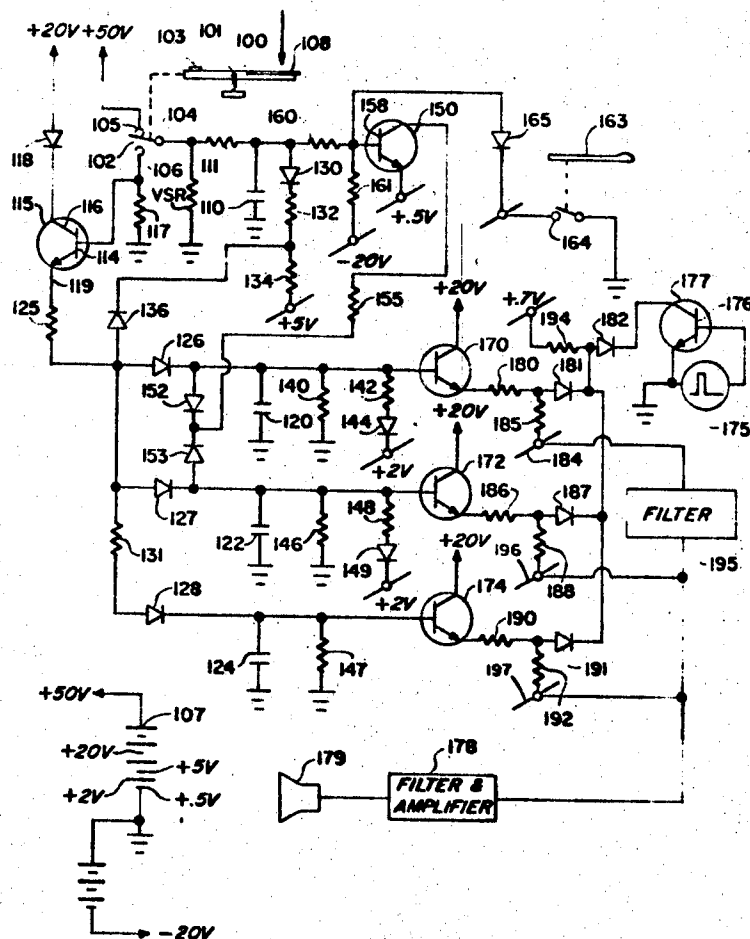
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3,516,321 6/1970 Harris 84/1.26 X

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[54] **ELECTRONIC PIANOLIKE MUSICAL INSTRUMENT**
5 Claims, 2 Drawing Figs.

[52] U.S. Cl. 84/1.26,
84/1.1, 84/1.27, 84/DIG. 8, 84/DIG. 25, 84/1.27
[51] Int. Cl. G10h 1/02,
G10h 5/00
[50] Field of Search 84/1.24,
1.26, 1.13, 1.01, 1.1, 1.27

ABSTRACT: An electrical musical instrument capable of substantially duplicating the sounds of a conventional pianoforte, uses a continuously oscillating tone generator. Gating circuits deliver signals from the tone generator to an output system with a peak intensity proportional to the velocity with which the playing keys are struck. Damper circuits are provided, and a sustaining pedal operates in conjunction with the dampers in a manner analogous to the action of a sustaining pedal in a conventional piano.



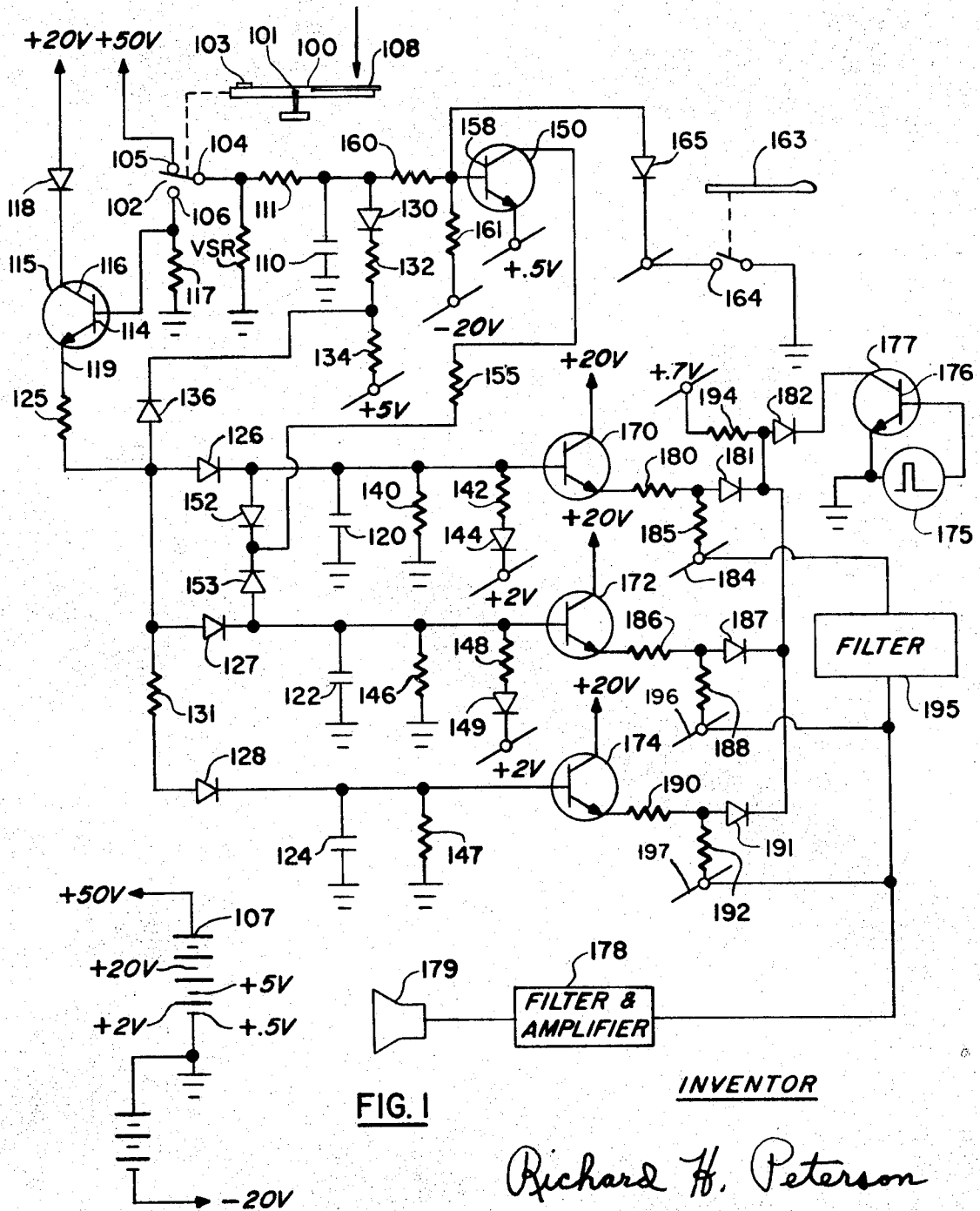
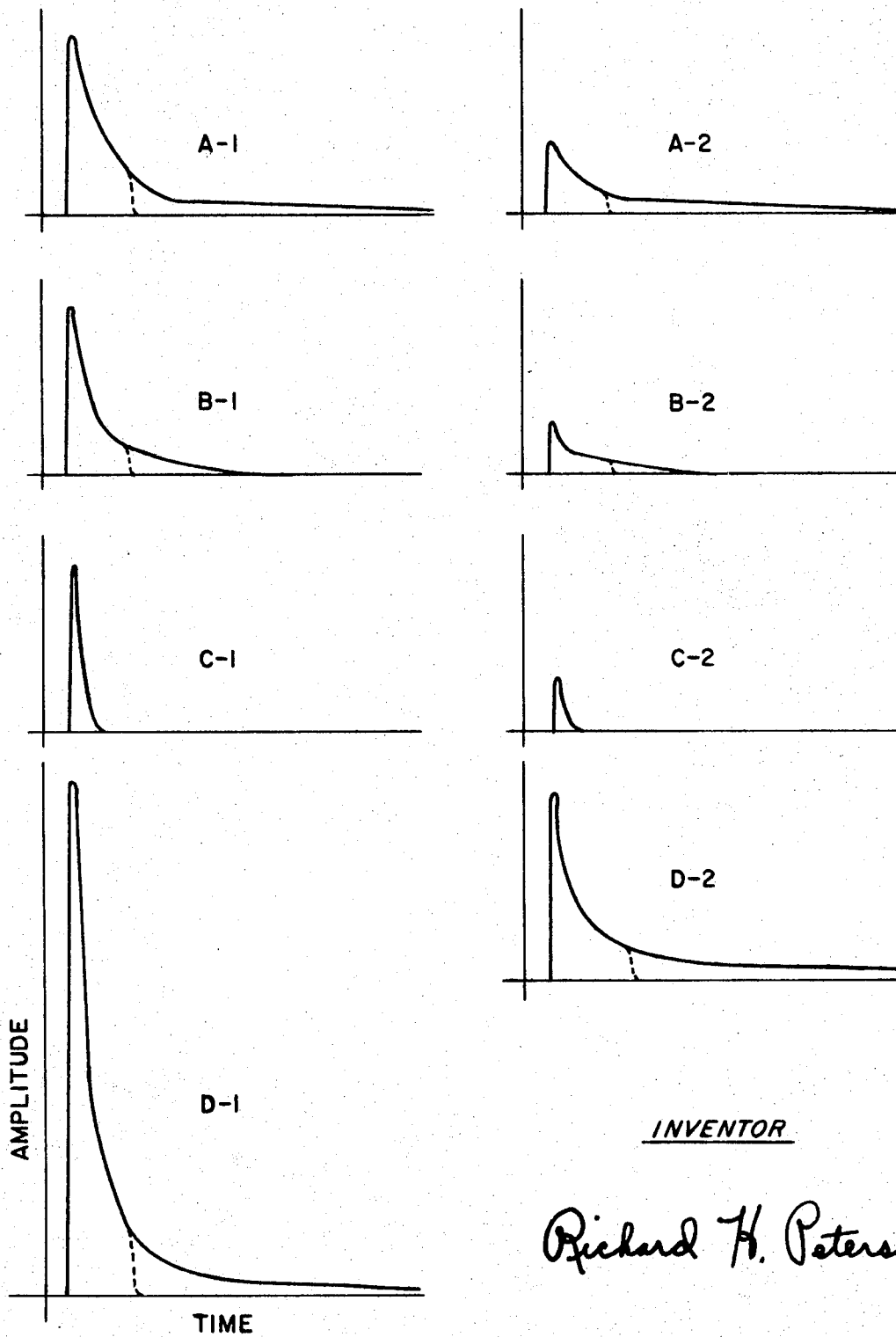


FIG. 1

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FIG. 2

ELECTRONIC PIANOLIKE MUSICAL INSTRUMENT

This invention relates to an electronic musical instrument capable of producing the tonal quality and the touch dynamics of a conventional pianoforte.

In my prior U.S. Pat. No. 3,444,306 issued Apr. 30, 1969, I disclose a system for producing pianolike sounds from electronically generated, harmonic rich, impulses by means of key controlled gating circuits.

The present invention is an improvement upon the instrument of the earlier patent.

SUMMARY OF THE INVENTION

In one embodiment of the present invention an oscillation generating system produces, for each note, a tone frequency impulse having a repetition rate corresponding to the frequency of the note and a pulse width equal to approximately 12½ percent of the period. A plurality of gates are associated with each oscillation generator. A velocity sensitive circuit associated with each playing key produces a plurality of envelope determining pulses, each having a peak potential dependent upon the velocity with which the key is operated. Each operates a related gating circuit causing signal to be delivered from the tone generator to the output system with a predetermined amplitude versus time characteristic. The total signal delivered to the output system in response to the striking of a single key is the sum of the plurality of signals delivered through the plurality of gates. By tailoring the shape of each of the envelope-determining pulses, a wide dynamic range of volume levels can be obtained and the shape of the tone intensity envelope is always substantially the same regardless of the intensity with which the key is struck.

The velocity sensitive circuit for each note is controlled by weighted playing key associated with a single pole double throw switch. The switch also controls a "damper" transistor which allows the tone to be quickly damped upon the return of the playing key to its inoperated condition. A sustaining pedal can be pressed to disable the damper transistors to duplicate the effect of the sustaining pedal in a conventional piano.

In the accompanying drawings:

FIG. 1 is a schematic circuit diagram for one note of an instrument according to the invention.

FIG. 2 is a series of curves showing the shape of certain pulses appearing at various points in the circuit. Referring first to FIG. 1, I have indicated at 100, a playing key which represents one of the 73 or 88 keys that typically make up a piano keyboard. The key rocks on pivot 101 and is maintained in a normal inoperative condition by the weight 103. Each key operates a keyswitch 102, having a movable contact 104 normally engaged with fixed contact 105. A force applied to playing surface 108 moves contact 104 away from 105 and then against contact 106. The terminal 105 is connected to a source of potential labeled plus 50 volts. The battery 107 represents a power supply capable of supplying this voltage. When key 100 is in its normal position, a capacitor 110 is charged from the power supply 107 through resistor 111. Upon operating the key 100 the charged capacitor 110 is connected to the base 114 of transistor 115 by way of contact 106. Transistor 115 is an emitter follower having its collector 116 connected to the plus 20 volt terminal of power supply 107 through diode 118. Three capacitors 120, 122 and 124 are connected to the emitter 119 through respective coupling diodes 126, 127 and 128. Resistor 125 limits the peak current through transistor 115 to a safe value. The rate of rise of the voltage that appears across capacitors 120 and 122 when the key 100 is operated is also influenced by the size of resistor 125. Similarly resistor 131 determines the rate of charge of capacitor 124. Connected to one terminal of capacitor 110 is a network consisting of the diode 130, and resistors 132 and 134. The lower terminal of this network connects to the plus 5 volt tap on the power supply 107. This network is for the purpose of discharging capacitor 110 at a predetermined rate during the time interval that the contact 104 has been dis-

connected from contact 105 and until it makes with contact 106. Thus the potential delivered to the base 114 of transistor 115 is dependent upon the velocity with which the switch is moved by the playing key from contact 105 into contact with 106. As soon as the capacitor is connected to the base 114, a voltage appears on the emitter 119, and the capacitors 120, 122 and 124 are substantially instantly charged through their respective diodes 126, 127 and 128. At the same time, this voltage is fed back through diode 136 to the junction of resistors 132 and 134 with the result that diode 130 is back biased thus preventing a further rapid decay of the voltage across capacitor 110. This feed back circuit allows capacitors 120, 122 and 124 to be charged to a higher level with a given keying supply voltage (applied to contact 105) than would otherwise be possible. The 5 volt potential in series with the shunt network is for the purpose of determining a minimum strike amplitude regardless of how slowly the key is depressed. By adjusting the value of resistors 132 and 134 and the voltage applied to the bottom of resistor 134, it is possible to adjust the "feel" of the key over a wide range.

Essential to proper operation is the weight 103 attached to the key, which controls the translation of the energy imported by the players hand into the proper velocity of keyswitch actuation. Associated with capacitor 120 is resistor 140 which immediately begins to discharge capacitor 120 and thus determines the decay of the voltage pulse that has been initiated by the depression of the playing key. Resistor 142 and diode 144 form an additional discharge path for capacitor 120 which is effective so long as the voltage on capacitor 120 exceeds the voltage applied to the lower terminal of diode 144 (which is indicated on the schematic as plus 2 volts).

Curve A—1 in FIG. 2 thus shows the shape of the pulse that is generated across capacitor 120 in response to the operation of keyswitch 102 by a sharp blow delivered to key 100. Curve A—2 shows the pulse developed at the same point in response to a relatively gentle blow delivered to key 100. Simultaneously, similar but somewhat differently shaped pulses will be developed across capacitors 122 and 124 but because the value of the resistors 146, 147 and 148 are different from those of corresponding resistors associated with capacitor 120, the pulse developed across capacitor 122 will be substantially shorter in duration than that developed across capacitor 120; and the pulse developed across capacitor 124 will be shorter still. Referring again to FIG. 2, the corresponding pulses appearing across capacitor 122 are shown at B—1 and B—2 and those across 124 are shown at C—1 and C—2.

THE DAMPER CIRCUIT

Because of the amount of time that it takes for switch contact 104 to be moved from contact 105 to contact 106 even with a hard blow to key 100, and because of the shunt circuit across capacitor 110, it is never possible for a charge of more than about plus 30 volts to be delivered to the base 114 of transistor 115. Transistor 150 is a damper transistor whose base 158 is connected to the capacitor 110 through resistor 160. The base 158 is also connected to a source of minus 20 volts through resistor 161. It can be seen that as long as switch contact 104 is in contact with contact 105, a positive potential will be delivered to the base 158 that is greater than the negative potential delivered through resistor 161, and the result is that transistor 150 will saturate and provide discharge paths across capacitors 120 and 122 through diodes 152 and 153, resistor 155 and the collector emitter junction of transistor 150. When switch contact 104 is moved away from contact 105 however, the voltage across capacitor 110 almost instantly discharges to a point where the base 158 receives a negative bias through resistor 161 sufficient to cut off transistor 150 and the discharge paths across capacitors 120 and 122 are removed. The dotted portions of the curves of FIG. 2 show the damping effect upon the shape of the pulses across capacitors 120 and 122 when at a given point in time playing key 100 is released, allowing the damper transistor to

become effective. Since the damper circuit includes resistor 155, the rapidity of the damping effect is easily adjusted by adjusting the value of this resistor. A damper pedal 163 is connected to operate a switch 164 which shorts the base 158 to ground through diode 165 whenever the pedal is depressed. This effectively prevents the damper circuit from operating and thus duplicates the action of the sustaining pedal in a conventional piano.

THE GATING CIRCUIT

Capacitance multiplying emitter follower transistors 170, 172 and 174 are associated respectively with capacitors 120, 122 and 124. Each of these transistors has its collector circuit connected to the plus 20 volts potential. The pulses across the respective base capacitors are repeated at the emitters and these pulses are used to operate the diode gating circuits that "Key" signal from the tone generator 175 to the output system which includes amplifier 178 and loud speaker 179.

The tone generator 175 is a pulse generator, and in a preferred embodiment generates a rectangular pulse having a pulse duration equal to one-eighth of the period of the repetition rate. The low order harmonic configuration of such a wave is very close to that of a piano string struck at the nodal point of the eighth harmonic. The tone generator 175 is connected to the base 176 of transistor 177. The emitter is connected to ground. Transistor 177 thus acts as a switch as it is periodically driven into saturation by the positive excursion of the signal frequency pulse generated by the tone generator 175. Whenever a voltage appears on the emitter of transistor 170, in response to the operation of the playing key 100, this voltage will be applied to the collector of transistor 176 through resistor 180 and diodes 181 and 182. Whenever transistor 177 is driven into saturation, the voltage at the junction of resistor 180 and diode 181 will drop to substantially zero volts; this point being effectively grounded through the two diodes and the transistor, all in their saturated states. During the portion of the signal cycle when transistor 176 is not conducting, the voltage at the junction of resistor 180 and diode 181 will be substantially the same as the voltage at the emitter of transistor 170. Thus the "envelope determining pulse" appearing on the emitter of transistor 170 is effectively modulated or "chopped" by the transistor switch 177. This modulated signal is connected to tone collecting bus bar 184 through resistor 185. It should be emphasized that the output appearing on bus bar 184 is a series of signal frequency rectangular pulses having the envelope profile of the pulse of DC voltage that was formed at the emitter of transistor 170 by the velocity sensitive pulse forming circuits previously disclosed. A similar gate including resistors 186 and 188 and diode 187 is associated with transistor 172 to control the potential delivered to bus bar 196. Still another similar gate consisting of resistors 190 and 192 and diode 191 is associated with transistor 174, and controls the potential delivered to bus bar 197. Diode 182 is common to all of the gates, its purpose being to minimize the slight amount of gate leakage that might occur through the small interelectrode capacitance of the main gating diodes 181, 187 and 191. Resistor 194 is a load resistor whose impedance is high enough to have a negligible effect on the ordinary operation of the circuit, but low enough relative to the impedance represented by the capacitance of diode 182 at signal frequencies, to shunt these leakage signals to ground when the gates are in their nonconducting or "blocking" condition. A voltage of approximately ½ volt is applied in series with resistor 194 to compensate for the forward voltage drop characteristic of the diode 182. This allows a smoother decay curve at very low signal intensities. The output signals from tone collecting buses 184, 196 and 197 are applied to the output system which includes amplifier 178 and loudspeaker 179. Filter circuits to attenuate the upper order harmonics may be included in the amplifier 176 to make the tone more faithfully duplicate the harmonic structure of a conventional piano string. An additional low pass filter 195 is

inserted in the connection between tone collecting bus 184 and amplifier 178 to provide additional filtering of the signal on output bus 184. This causes the signal delivered by the loudspeaker 177 to gradually change in tonal character as the tone decays and thus duplicates the similar change in tone quality that occurs in a conventional piano as the tone decays in amplitude.

It should be emphasized, that the total tone signal heard by the listener is the composite of signals gated through the three separate gating circuits, and that the shape of the composite tone signal intensity envelope duplicates the shape of the geometric addition of the three envelope determining pulses. Curve D-1 of FIG. 2 is the composite of curves A-1, B-1, and C-1, and curve D-2 is the composite of curves A-2, B-2, and C-2.

Others may readily adapt the invention for use under various conditions of service by employing one or more of the novel features disclosed or equivalent thereof. For example, one or more of the gating circuits shown might be connected to a different tone generator from the others in order to enhance the chorus effect, or one or more additional sets of gates might be operated from the velocity sensing circuits at either octave or unison pitches in order to achieve additional tonal effects.

Although the circuit as previously described is generally preferred, a silicon carbide or other voltage sensitive resistor might be substituted for, or used in addition to, the shunting circuit including diode 130 and resistor 132. A silicon carbide varistor has been effectively used for this purpose and has been shown in FIG. 1 (labeled V.S.R.) to illustrate this alternative.

As at present advised, with respect to the apparent scope of my invention I desire to claim the following subject matter.

1. In an electrical musical instrument:

an oscillation generator for producing signal impulses at a frequency corresponding to the pitch of a musical note to be produced;

a playing key;

means associated with said playing key and adapted upon the actuation of said playing key to simultaneously initiate a plurality of discrete envelope determining pulses, each having a peak amplitude proportional to the velocity with which said playing key is operated, and each having different decay characteristics;

an output system;

a plurality of gating circuits respectively associated with said plurality of envelope determining pulses and each adapted to gate signal from said oscillation generator to said output system with an amplitude which is a function of the amplitude of its associated envelope determining pulse.

2. The combination according to claim 1 including additional filter means associated with at least one of said plurality of gating circuits, such that the combined signal delivered to said output system varies in harmonic content as the tone decays.

3. Touch responsive tone producing circuit for an electrical musical instrument comprising;

a playing key having an operating surface, and adapted to be moved between a normal and an operated position;

a capacitor;

a keyswitch associated with said playing key and adapted to complete a first circuit, including said capacitor, when said playing key is in its normal position, and to complete a second circuit, including said capacitor, when said playing key is in its operated position;

a shunting circuit associated with said capacitor;

electronic means including said capacitor and said keyswitch means, and adapted to produce a tone signal having an amplitude which is a predetermined function of the current flowing in said shunting circuit and of the time period during which said playing key is in transit between its normal and operated positions;

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- a mass operatively associated with said playing key; said mass and key normally tending by gravity to move to normal inactive position; said mass and key having inertia resisting the acceleration of said playing key and said keyswitch.
4. A touch responsive tone producing circuit for an electrical musical instrument comprising:
- a playing key adapted to be moved between a normal and an operated position;
 - a single pole-double throw keyswitch operatively associated with said playing key;
 - a first capacitor connected to said keyswitch;
 - an impedance connected across said first capacitor;
 - first means associated with said keyswitch for rapidly charging said first capacitor when said playing key is in its normal position;
- a second capacitor;
- second means associated with said keyswitch and including a first emitter follower transmitter for charging said second capacitor to a potential dependent upon the velocity with which said playing key is moved between its normal and its operated positions;
- a separate damper circuit including an electron switching device and forming a discharge path across said second capacitor; and, third means associated with said keyswitch for causing said damper circuit to become effective whenever said playing key is in its normal position.
5. A combination according to claim 4 and including a sustaining pedal adapted to selectively disable said damper circuit.

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