United States Patent

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[54] **PIANO TONE SIMULATION SYSTEM WITH PIEZOELECTRIC GENERATOR**
12 Claims, 6 Drawing Figs.

[52] U.S. Cl. 84/1.13, 84/1.14, 84/1.26, 310/8.1, 310/8.2, 310/8.3, 310/9.4
[51] Int. Cl. G10h 1/02, G10h 3/00
[50] Field of Search ..... 84/1.01, 1.04, 1.06, 1.13, 1.14, 1.16, 1.26, (P), 1.09, 1.1, 1.27, (PC); 310/8.1, 8.3; 307/108

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ABSTRACT: A piano action including a hammer having a felt head, the hammer striking a piezoelectric generator which generates a DC electric potential proportional to the force of the hammer blow. The potential generated momentarily turns on a transistor to charge a capacitor. The capacitor then discharges in accordance with a resistor to provide a wave envelope simulating that of a conventional piano.

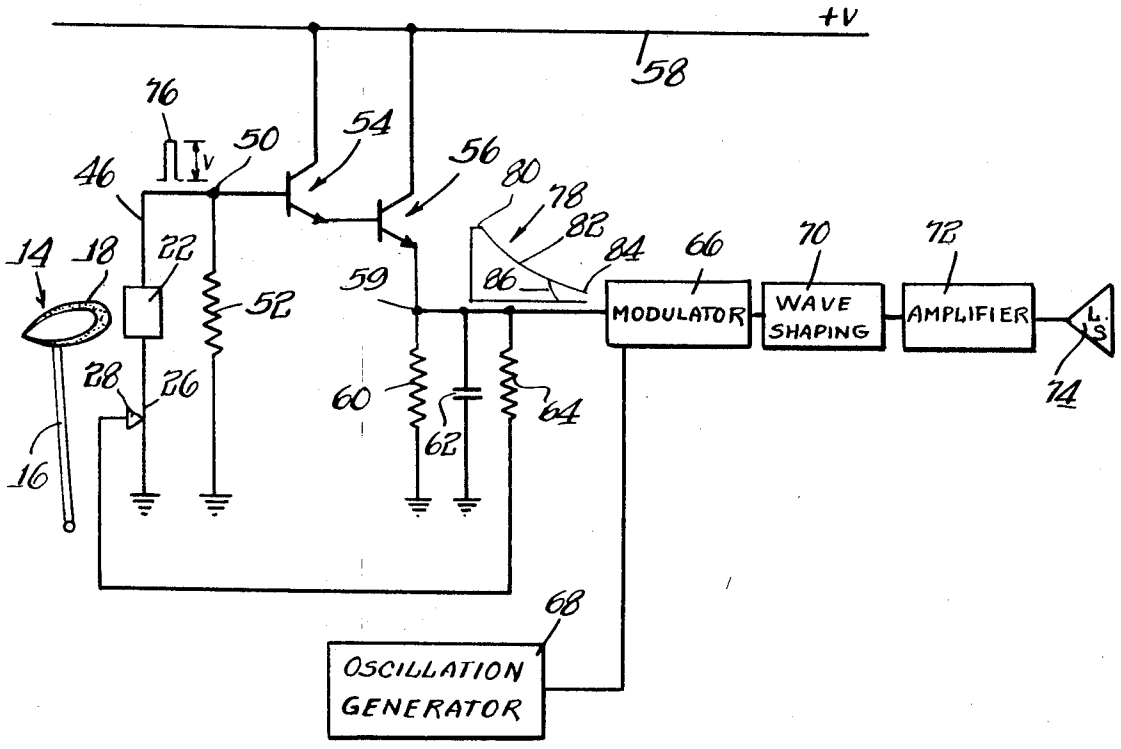


Fig. 1.

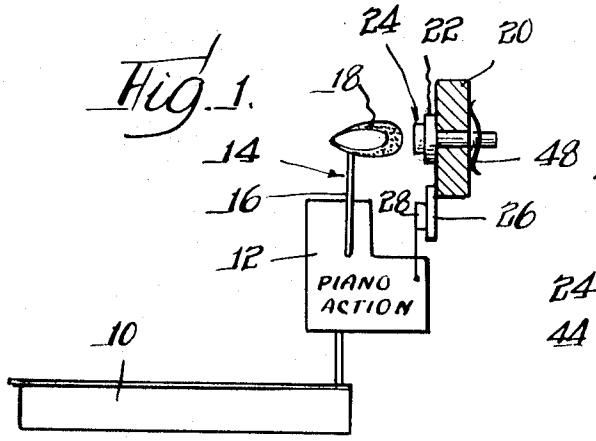


Fig. 2.

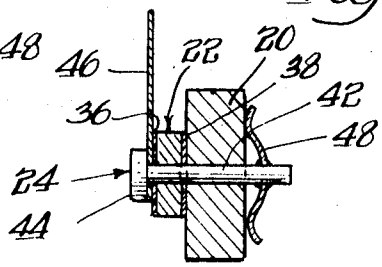


Fig. 3.

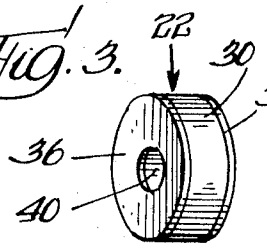


Fig. 4.

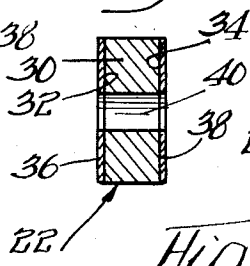


Fig. 5.

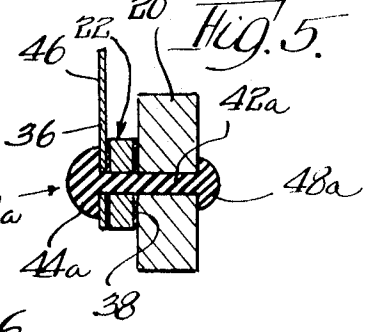
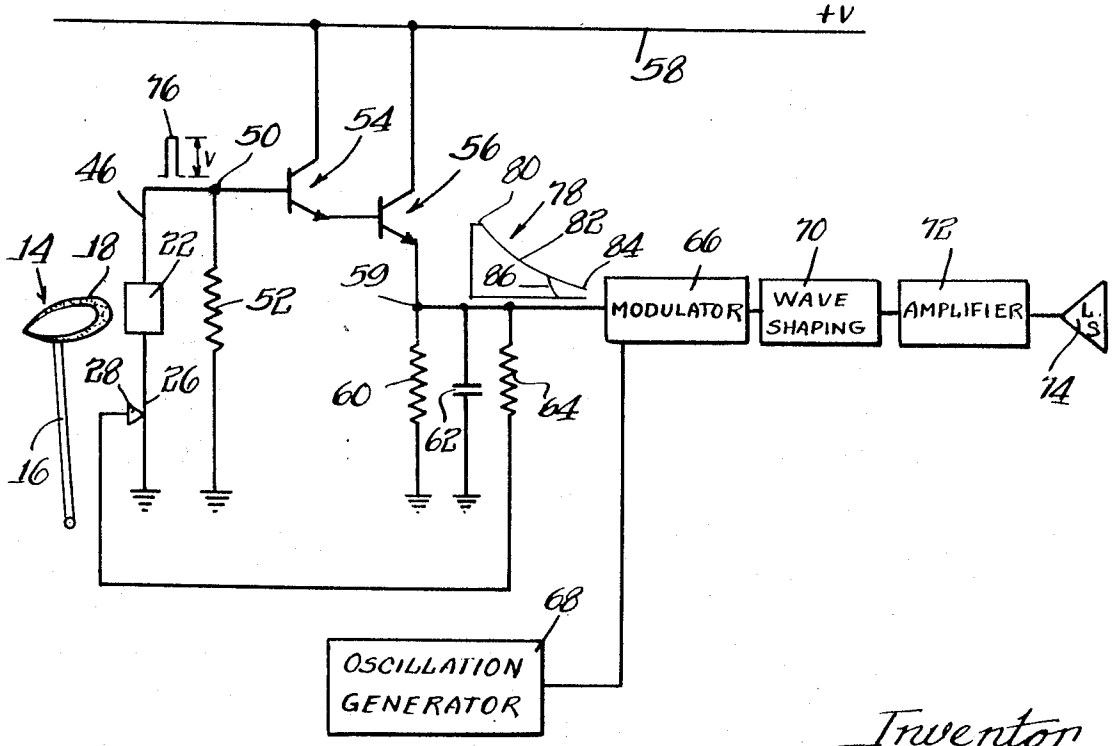


Fig. 6.



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PIANO TONE SIMULATION SYSTEM WITH PIEZOELECTRIC GENERATOR

Efforts have been made heretofore to produce electronic pianos in which the tones are generated purely electronically under the control of a piano keyboard. Heretofore it has been difficult or impossible, either from a technical or a financial standpoint, to provide the requisite tonal envelope to simulate true piano tones. As is recognized, a conventional piano with stretched strings percussively actuated by hammers inherently possesses a tonal envelope which initially reaches a maximum magnitude or intensity, and which thereafter decays at a predetermined or inherent rate until vibration stop, either after an extended time period, or upon release of the key so that the string is again engaged by a damper.

It is an object of the present invention to produce the tonal envelope of a conventional piano electronically.

More particularly, it is an object of this invention to utilize a more or less conventional piano action in conjunction with a mechanical-electrical transducer to produce an electric control signal proportional to the magnitude of the finger force imposed on the key of an electronic piano.

Another specific object of the present invention is to combine a percussively actuated piezoelectric transducer with an electrical circuit to simulate electrically the tonal envelope of a string piano.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

FIG. 1 is a semischematic side view of a piano action in combination with a piezoelectric transducer in accordance with the present invention;

FIG. 2 is an axial sectional view of the transducer and mounting thereof in accordance with the present invention;

FIG. 3 is a perspective view of the piezoelectric transducer;

FIG. 4 is an axial sectional view of the piezoelectric transducer;

FIG. 5 is a view similar to FIG. 2, showing a modification of the mounting; and

FIG. 6 is an electronic wiring diagram in combination with other parts shown in block form illustrating the electrical concepts of the present invention.

Turning now in greater particularity to the present invention, an ordinary piano key **10** is connected in conventional fashion to a piano action **12** including a hammer **14** having a shank **16** and a head **18** with the usual felt covering. As will be understood, in any piano built in accordance with the present invention there would be a plurality of such keys, actions and hammers.

A metallic mounting rail and common electric contact **20** are disposed opposite the hammer heads **18**. In the present example, the hammer shank is shown in substantially vertical position as in an upright piano action. However, the principles are equally applicable to a grand piano-type action. A piezoelectric transducer **22** is mounted on the rail **20** by means of a stud **24** directly opposite the hammer for percussive engagement thereby. A grounded damper base **26**, which may be integral with or fixed to the rail **20**, is engageable by an electrically conductive damper **28** operated by the piano action in conventional fashion.

The piezoelectric transducer **22** may be seen in greater detail in FIGS. **3** and **4**, and comprises a ring of ceramic material of the type generating an electric potential when it is distorted. Barium titanate is one satisfactory example for the material. The ring **30** is of generally cylindrical configuration, having opposite flat faces **32** and **34** with conductive material **36** and **38**—for example, silver fired thereon—for electric connection or electrodes. A central bore **40** extends through the ring.

Turning now to FIG. **2**, the transducer **22** is mounted on the metallic rail **20** by means of a stud **24** as aforesaid. The stud is of a plastic material, and comprises a shank **42** extending through the axial bore **40**, and also comprises a head **44** serving as an anvil against which the hammer strikes. An electric connector such as a wire or metallic strip **46** is held tightly

against the front electrode **36** by the stud head **44** to make electric connection with the transducer, while the stud likewise holds the rear electrode **38** in tight electrical engagement with the metallic rail **20**. A resilient fastener **48** of the type generally known as a speed clip engages the rear end of the shank **42** which projects beyond the rail **20**, and thereby maintains a resilient tension on the stud, whereby to hold all of the parts in tight engagement. Whenever the hammer **18** engages the anvil **44**, the piezoelectric transducer **22** is compressed axially, causing it to produce a pulse of DC potential. The open circuit voltage produced is about 70 volts, and this is reduced to about 7 volts under a load of about 800,000 ohms.

An alternative mounting construction is shown in FIG. **5** wherein most of the parts are similar to those previously described and therefore are identified by similar numerals. The distinction resides in that, rather than having a plastic stud and speed clip for mounting the parts, there is a rubber stud **24***a* having a shank **42***a* extending through the electrical connector **46**, the transducer **22**, and the rail **20**. An integral rubber head **44***a* traps the electric connector and the transducer, while an integral enlargement **48***a* on the opposite end takes the place of the speed clip to hold the shank **42***a* under tension. The advantage to this form of the invention is that a blow on the head **44***a* causes not only an axial force to be imposed on the transducer, but also a radial force due to distortion of the rubber under the blow. This causes a greater voltage to be generated.

Attention now should be direction to FIG. **6** wherein the hammer is shown somewhat diagrammatically, and the piezoelectric transducer **22** is simply shown as a block. The rail **20** and the extension **26** thereon are grounded, and the electrical contact damper member **28** is at ground potential due to its engagement with the extension **26**. The lead **46** is connected to a junction **50**, and this junction is connected through a resistor **52** to ground. In accordance with the illustrative example of the invention, the resistor is a 820,000 ohm resistor, which, as previously noted, cuts the output of the transducer to about 7 volts. The junction **50** also is connected to the base of a transistor **54** connected in a Darlington amplifier double transistor circuit. As is known in the Darlington circuit, the emitter of the first transistor is connected to the base of a second transistor **56**, both being supplied from a positive voltage line **58** connected to the collectors.

The emitter of the second transistor **56** is connected to a junction point **59** which is grounded through a resistor **60**. A capacitor **62** is connected in parallel with the resistor **60**. In addition, a resistor **64** ties the junction point **59** back to the damper contact **28**.

The junction point **59** is connected to a modulator **66**, and an oscillation generator **68** also is connected to the modulator. The modulator may be connected through a wave-shaping network **70**, if desired, to an amplifier **72**, or the wave-shaping network may be omitted. The amplifier **72** includes a conventional volume control for determining the overall level of the instrument, and the amplifier is connected to a loudspeaker **74** or other suitable electroacoustic transducer for converting the amplifier oscillations into audible tones.

Whenever the key **10** is depressed, the hammer **14** flies forward to bring the hammer head **18** into impact engagement with the anvil **24** associated with the transducer **22**. The voltage developed by the transducer is directly proportional to the kinetic energy of the hammer. The voltage is produced for only a brief time, and appears as a pulse **76** of amplitude V. The amplitude $V=Kmv^2$, wherein K is a constant, m represents the mass, and v represents the hammer velocity at the time of impact.

The biasing of the Darlington amplifier circuit including the transistors **54** and **56** is such that the transistor **56** is normally off, and the capacitor **62** is not charged. However, the pulse **76** acts through the transistor **54** to turn the transistor **56** on very briefly to a degree proportional to the height of the pulse **76** and for a time corresponding to the width of the pulse, and thus to charge the capacitor **62**, it being borne in mind that the

damper contact 28 is retracted by the piano action at the same time as the hammer flies forward. Accordingly, the capacitor charges as indicated on the wave envelope 78 above the capacitor to a potential indicated at 80. Promptly upon cessation of the pulse at 76, the transistor 56 is again shut off, and the charge on the capacitor begins to decay through the resistor 60 as indicated in the wave portion 82. Eventually this may decay to an insignificant or zero value as indicated at 84. However, if the key is released, the damper contact 28 again engages ground, and the resistor 64 is connected in parallel with the resistor 60 more rapidly to discharge the capacitor 62 as indicated at 86. As will be understood, the shapes of the wave portions 82 and 86 are determined by the values of the resistors 60 and 64, and these will vary from one part of a piano keyboard to another in accordance with the normal decay time to be expected from a piano of any particular type. Furthermore, the decay rate will be influenced somewhat by the type of piano that it is desired to simulate.

The envelope 78, being applied to the modulators 66, modulates the oscillations from the oscillator generator 68 which are of a type to simulate a piano tone, thereby to produce the initial high volume, and thereafter diminishing or decaying in the waveform of a conventional string piano. The modulated oscillations are amplified by the amplifier 72 and are converted into audible sound by the loudspeaker 74, thus to simulate a conventional piano sound.

As should now be apparent, I have disclosed a means for producing a wave envelope simulating that of a conventional piano by rather simple means and at minimum cost. The maximum amplitude of the wave envelope is determined by the impact of the player's finger on the key, just as it is in a conventional piano, and the decay of the wave envelope is in accordance with predetermined constants, and also in accordance with the damper action.

I claim:

1. Musical instrument tone generating apparatus including a piezoelectric transducer, impulse means for exciting said transducer including a finger-operated key, a mechanical hammer, and means interconnecting said key and said hammer and operative upon depression of said key impulsively to bring said hammer from a rest position into mechanical engagement with said transducer to cause said transducer to produce an electric potential, voltage storage means connected to said piezoelectric transducer and charged to a potential corresponding to the voltage generated by said piezoelectric transducer, and means for discharging said voltage storage means at a predetermined rate.

2. Musical instrument tone generating apparatus as set forth in claim 1, and further including means operatively connected to said key and connected to said voltage storage means for more rapidly discharging said voltage means upon release of said key.

3. Apparatus as set forth in claim 1 wherein said voltage storage means comprises a capacitor.

4. Apparatus as set forth in claim 2 wherein said voltage storage means comprises a capacitor.

5. Musical instrument tone generating apparatus including a piezoelectric transducer, impulse means for exciting said transducer including a finger-operated key, a mechanical hammer, and means interconnecting said key and said hammer and operative upon depression of said key impulsively to bring said hammer from a rest position into mechanical engagement with said transducer to cause said transducer to produce an electric potential, a capacitor, means connecting said piezoelectric transducer and said capacitor including electronic valve means for charging said capacitor, said valve means being normally off and pulsed on by said piezoelectric transducer to charge said capacitor to a value determined by the voltage generated by said piezoelectric transducer, and resistor means for discharging said capacitor at a predetermined rate.

6. Apparatus as set forth in claim 5 and comprising means constituting an additional discharge path for said capacitor connected to said capacitor and connected in circuit when said key is released.

7. Apparatus as set forth in claim 5, and further including a source of oscillations, a modulator, means connecting said capacitor and said source of oscillations to said modulator for modulating said oscillations in accordance with the state of charge of said capacitor, an amplifier for amplifying the modulated oscillations, and electroacoustic transducing means for converting the amplified oscillations into audible sounds.

8. Apparatus as set forth in claim 7, and further including means operatively connected to said capacitor and to said key constituting an additional discharge path for said capacitor when said key is released.

9. Apparatus as set forth in claim 1 wherein the mechanical-electric transducer comprises a piezoelectric ring, a base, means mounting said ring on said base including a stud having a head overlapping said ring as an anvil, and a shank extending through said ring and said base, means exerting a resilient pressure on said shank in a direction away from said head, said key-operated impulse means percussively engageable with said anvil to cause said piezoelectric ring to develop a voltage proportional to the percussive impulse on said anvil.

10. Apparatus as set forth in claim 9 wherein said stud comprises a plastic stud, and wherein the means exerting resilient pressure on said shank comprises means lying on the opposite side of said base in gripping engagement with said shank and pulling thereon.

11. Apparatus as set forth in claim 9 wherein said stud is made of rubber, thereby exerting a radial as well as axial force on said ring when said anvil is percussively engaged.

12. Apparatus as set forth in claim 11 wherein the stud includes an integral rubber enlargement on the end of said shank opposite said anvil as an anchor.