April 26, 1966 J. MARKOWITZ ETAL 3,248,470

ELECTRONIC PIANO HAVING MEANS RESPONSIVE TO THE VELOCITY OF THE ACTION

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FIG. 1

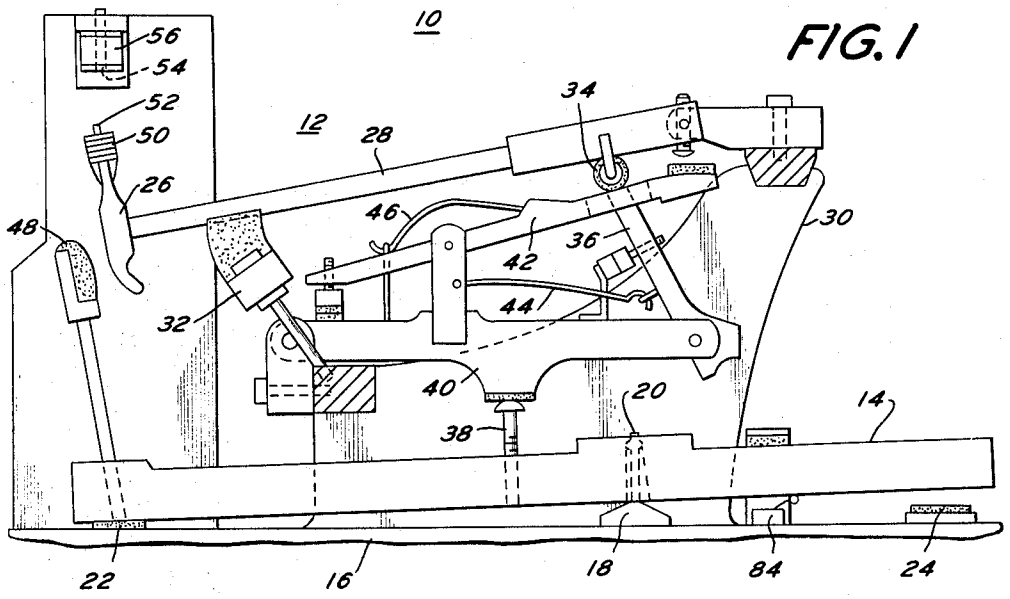
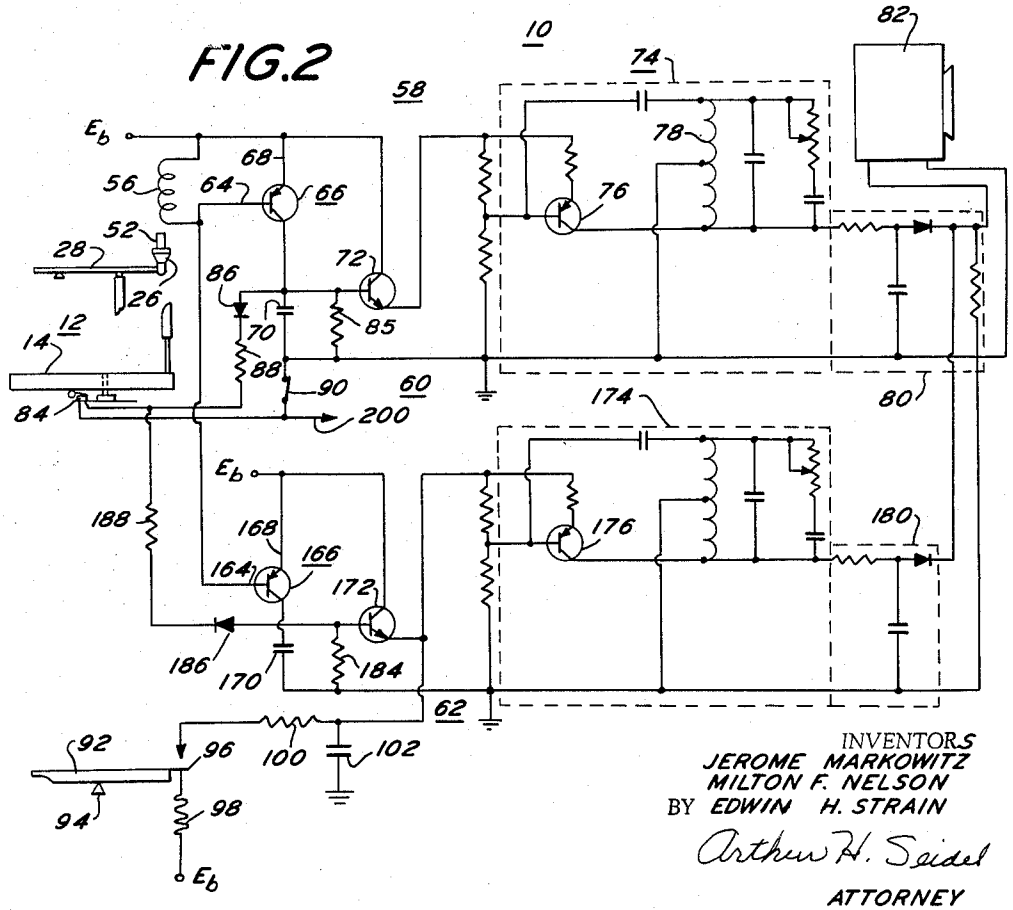


FIG. 2



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ELECTRONIC PIANO HAVING MEANS RESPONSIVE TO THE VELOCITY OF THE ACTION

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In general, this invention relates to a new and improved electronic musical apparatus utilizing electronic techniques for producing the sound of a conventional piano and/or organ. More particularly, it is directed to an electronic piano which may be utilized with any of the known piano actions with the same degree of control as is presently possible with conventional pianos.

The conventional piano produces its characteristic tone by means of an action consisting of primarily mechanical levers by means of which a felt hammer can be caused to strike one or more taut steel strings with a wide range of velocity and force causing the strings to vibrate. These vibrations are transmitted to a sounding board for amplification. An extremely high order of control can be exerted on the amplitude and other tonal characteristics of the sound by a skilled performer. The wide range of amplitude results mainly from the construction of the mechanical linkage between the key which is struck by the performer and the felt hammer, and this led to the original name of the instrument, the pianoforte.

In the past, electrification of pianos has fallen along certain conventional lines. That is, developments in the past have been directed to the electrical amplification of the sound produced by a piano. These techniques included utilizing the strings to excite electromagnetic or electrostatic pickups, or by having the hammers strike vibrating reeds which produced output signals in accordance with their mode of vibration. However, these techniques produced pale imitations of the sound produced by a conventional piano and were therefore not acceptable except as novelty items.

In accordance with the teachings of the present invention, an electronic piano is disclosed which utilizes a conventional piano action plus electronic means for producing an electrical signal which when amplified and transduced by a suitable speaker will produce a piano-type tone. A piano constructed with the electronic means of the present invention resembles a conventional piano in respect to the keyboard and key action, but the strings and sounding board are replaced by electronic components.

The electronic means is operative from the felt hammer of the piano action to produce a signal in accordance with the velocity of the hammer. This is similar to operation of the strings of a conventional piano. Each note on the piano scale is produced electronically with its amplitude dependent upon the force and velocity of the hammer. Since the art of electronic tone generation has reached a high degree of sophistication, it is possible to design a piano with selective dynamic variations which would enable it to match or better the sound of the finest conventional pianos presently in use. Further, this can be achieved with a unit which is considerably lighter and smaller in size than most of the conventional pianos.

Still further, by utilizing static electronic components, the electronic piano need only be tuned in yearly intervals as opposed to conventional pianos which may go out of tune even after one playing.

Therefore, it is the general object of this invention to avoid the foregoing and other difficulties of the prior art

practices and to achieve the results discussed above by the provision of a new and improved piano utilizing electronic tone generation techniques.

A further object of this invention is the provision of a new and improved electronic piano capable of producing musical tones directly from the piano action by electronic components substituted for the standard strings and sounding board.

A still further object of this invention is the provision of a new and better electronic piano which utilizes a velocity sensitive transducer operative from the felt hammer of a piano action to produce a piano-type tone normally associated with the particular key being struck.

Another object of this invention is to produce a new, better and lighter weight piano which incorporates all of the features of tone variation possible in conventional pianos.

Still another object is the provision of a new and better piano which requires tuning only at infrequent intervals by the utilization of electronic sound producing components.

A further object of this invention is to provide an electronic tone generator capable of producing a piano-type tone in response to a velocity sensitive key action and/or to produce an organ-like sound of sustained amplitude when operated from an organ-type key contact arrangement.

Other objects will appear hereinafter.

For the purpose of illustrating the invention, there is shown in the drawings a form which is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

In FIGURE 1, there is shown a side view of a standard piano action incorporated in the piano of the present invention.

FIGURE 2 is a schematic showing of the electronic means for producing the piano tone associated with the key of FIGURE 1.

In FIGURE 1, there is shown a portion of the electronic piano and/or organ tone generator **10** of the present invention. The tone generator **10** includes a grand piano action **12** having a key **14** mounted on a key frame **16** for pivotal movement about a balance rail **18**. The balance rail **18** has an upstanding balance key pin **20** extending through a hole provided in the key **14**. The key frame **16** has a pair of cushions **22** and **24** associated with each end of the key **14** to insure a smooth limit stop for the movement of the key **14**. The piano action **12** is intended to transmit downward movement of the key **14** into upward movement of the hammer **26** which is attached to a suitable hammer shank **28** pivotally secured to a frame **30**. The hammer shank **28** rests on a hammer rest **32**.

The hammer shank **28** has a hammer shank knuckle **34** associated therewith resting on a suitable jack or grand fly **36**.

The key **14** has a capstan screw **38** integral therewith and utilized to transmit rotative movement to a suitable support **40** pivoted about the frame **30**. The jack **36** is pivoted about the other end of the support **40** so that upward movement of screw **38** causes the jack **36** to force the knuckle **34** of the hammer shank **28** upwardly and provide upward movement of the hammer **26**. The jack **36** is guided in this movement by a balancer **42** pivotally mounted about a top flange of support **40**. The jack **36** is further returned to its initial position by a suitable repetition spring **44** and the balancer **42** is returned to its initial position by a repetition spring **46** to thus aid in

biasing the key **14** to its released position shown in FIGURE 1.

The key **14** has a hammer check **48** at the end thereof to cushion the return of the hammer **26** after the completion of a stroke.

All of the elements discussed above form a portion of the grand piano action **12** and are conventional. Any other type of piano action, such as an upright action, which would be desired by the designer could be utilized in place of the grand piano action **12**. The piano action in itself does not form any portion of the present invention.

The hammer **26** has at its striking end a cushion **50** surrounding a core **52**. The core **52** is adapted to enter a suitable opening **54** in a coil **56** mounted above the hammer **26**. When the key **14** is struck by the player, the core **52** will enter the opening **54** in the coil **56**. The coil **56** acts as a transducer for the electronic piano tone generator **58** associated with the patricular piano action **12** discussed previously. The coil **56** transduces the movement of the hammer **26** directly into an electrical signal proportional to the velocity thereof.

As stated earlier, the importance of the piano rests upon its powerful and finely graduated tone and its convenience for the production of concerted music. Thus, the electronic piano tone generator **58** must be capable of utilization with a piano action of the general type to control one or more electronic oscillators. Further, means must be included in the tone generator to control the amplitude, the decay characteristics, and the pulse length of the oscillator to vary the tones produced thereby.

The circuitry forming the piano tone generator **58** can be divided into two separate circuits **60** and **62** which are utilized to simulate the sound generating from a two string tone. In a conventional piano, the strings are steel wires of graduated thickness and length, the larger being made heavier by being wound with copper wire. For each of the extreme upper and lower tones, only one wire is provided, but for most of the others, there are two or three wires which are tuned in unison and placed so that they will be simultaneously struck by a single hammer. The tone generator **58** is associated with a key utilized to produce one of the middle notes on the piano scale utilizing two strings in unison.

The components of the circuit **58** will be discussed in an integrated discussion of their operation. The coil **56** has one terminal connected to a source of supply E*b* and its other terminal to the base terminals **64** and **164** of transistors **66** and **166** respectively. The core **52** is a permanent magnet attached to the hammer **26** which will enter the coil **56** with a velocity that will be proportional to the velocity with which the key **14** is struck. Since the induced voltage in a coil is determined by the number of flux lines cut per unit time, the voltage developed across the coil **56** will be proportional to the velocity of the struck piano key within limits. The coil **56** voltage is applied between the base **64** and the emitter **68** of transistor **66** causing it to conduct and resulting in the charging of capacitor **70** from source E*b*. The charge on capacitor **70** causes transistor **72** to conduct and, in so doing, applies the voltage source E*b* to a Hartley oscillator **74**. The oscillator **74** includes a transistor **76** having a split inductance **78** utilized to tune the collector circuit of the transistor **76**.

The conductivity of transistor **72** varies with the charge on capacitor **70** or, in other words, with the voltage induced in the coil **56**. The oscillator **74** operates in a manner whereby the output will be a sine wave whose amplitude will be approximately proportional to the input voltage. The output of the Hartley oscillator **74** is applied through a wave shaping circuit **80** to the audio output and loudspeaker means **82**. The wave shaping circuit **80** is a standard means of imparting a string quality to the amplified and transduced sound.

In a conventional piano, there is normally provided a damper which will damp the string after the key is returned to its initial position. This damping is achieved in the piano tone generator **58** of the present invention by utilizing a switch **84** located below the key **14**. The contacts of switch **84** are opened when the key is struck and are closed when the key is in its normal position. After a key is struck and the capacitor **70** has charged as discussed previously, it discharges through a high resistance resistor **85** and transistor **72** so that it has a long time delay as would be normal when striking an undamped key on a piano. However, when the key is released and returns to its up or closed position, the capacitor **70** can discharge through diode **86**, low resistance resistor **88** and the now-closed contacts of switch **84** to ground. The capacitor **70** voltage will thus be quickly reduced to zero voltage and the oscillator **74** will be stopped.

A second set of contacts **90** are connected in series with the contact **84** and every other contact **84** associated with each key of a piano to perform the function of the sustaining pedal on the piano. The sustaining pedal on a conventional piano prevents the dampers associated with every key from dampening the vibration of their associated strings. The sustaining switch **90** performs this function by allowing the voltage on capacitor **70** to continue to decay through the resistor **85** and transistor **72** by opening the circuit betweeen resistor **88** and ground. Thus, the tone produced by the key **14** will decay for a period of time after the key has been released in the same manner as a conventional piano whose sustaining pedal has been pressed.

The portion **62** of the tone generator **58** has substantially the same components as the portion **60** as it is merely intended to reproduce a string exactly similar to the string reproduced by the portion **60** in the same manner as a two stringed tone on a conventional piano. The portion **62** will be controlled in the same manner and simultaneously with the portion **60**, and will provide the additional amplitude plus any possible interference effects which result from slight differences between the two identical circuits. The portion **62** has been noted with numerals exactly one hundred more than its associated components in portion **60**. For example, an oscillator **174** is provided exactly similar to the oscillator **74** discussed previously.

In a complete piano built in accordance with the principles of the present invention, each key will be associated with a similar set of components as described heretofore, but tuned to the required frequency. The sustaining contacts **90** would connect to a common bus **200** associated with all of the contacts similar to contact **84** associated with each key of the piano. Isolating diodes would be provided between each key to prevent interaction of the oscillators. A mechanical arrangement would be provided so that the sustaining pedal contacts **90** would be actuated by a foot pedal. Further, the piano could be designed to have a separate pedal which would only sustain the bass notes rather than all of the notes. Additionally, a sostenuto pedal could insure the sustaining of a tone only after the particular key had been struck. Still further, a soft pedal could be provided to act as an electronic substitute for the conventional soft pedal by switching out one portion of each tone generator having more than one oscillator. This would lessen the amplitude of the output signal of the tone generators in the same manner as is now done on conventional pianos. In the alternative, the soft pedal could proportionately lessen the amplitude of the output signals of the tone generators.

The tone generator **58** can additionally be utilized with a separate set of organ keys for producing an organ-like sound of sustained amplitude either separately or in combination with the piano discussed above. The organ keyboard has been shown representatively by the

organ key **92**. The organ key **92** rotates about a fulcrum **94** to open and close its associated contacts **96**. The key **92** is spring loaded to an open position by a conductive spring **98** connected to the voltage source E*b*. Upon pressing the key **92**, contacts **96** are closed completing a circuit from the voltage source E*b* through a resistor **100**, capacitor **102**, wave shaping circuit to the input of transistor **176** in oscillator **174**.

In the interest of economy, the organ contacts could be placed below the piano keys **14** and suitable switches arranged in the circuit to cut out the piano signal transducer while connecting the organ contact to the oscillators and vice versa.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

It is claimed:

1. An electronic piano comprising a key operated action, velocity sensitive transducer means for directly transducing the velocity of a struck key into an electric signal proportional thereto, a tuned circuit oscillator, and means for applying the electric signal to said tuned circuit oscillator to control the output of said tuned circuit oscillator, and audio output means connected to said tuned circuit oscillator.

2. The electronic piano of claim **1** wherein said action includes a hammer and means for controlling the movement of said hammer by said key, a core element on said hammer, said velocity sensitive transducer means including a coil, said core and coil being positioned to vary the inductance of said coil in accordance with the velocity of said hammer.

3. The electronic piano of claim **1** wherein said tuned circuit oscillator includes means for producing a characteristic tone signal whose amplitude varies with the input signal to said oscillator, an oscillator input means for connecting said oscillator responsive to said velocity sensitive transducer means.

4. The electronic piano of claim **3** wherein said velocity sensitive transducer means includes a transducer operative to provide a signal proportional to the velocity of said key, signal storage means energized by said transducer, said signal storage means being operative to store said transducer signal and transmit said transducer signal to said oscillator for a predetermined period of time.

5. The electronic piano of claim **3** including a second oscillator similar to said first-mentioned oscillator, said second oscillator being responsive to said velocity sensitive transducer means signal.

6. The electronic piano of claim **3** wherein said oscillator includes means for producing a sine wave output varying in amplitude in accordance with said velocity sensitive transducer means signal, said audio output means additionally including a wave shaping circuit, said wave shaping circuit including means to modify said oscillator sine wave output, means connecting a speaker to said wave shaping circuit, said wave shaping circuit including means to transmit a string-like tone signal to said speaker from said oscillator.

7. An electronic piano comprising a key, electronic transducer means for producing a signal in accordance with the force of the striking of said key, an electronic tone generator for producing a tone signal corresponding to said key and including means for varying the amplitude of said tone signals in accordance with the amplitude of said transducer means signal, and audio output means for producing an audio output in accordance with said tone signal.

8. The electronic piano of claim **7** wherein said tone generator includes at least two tone producing circuits, each of said tone producing circuits being substantially similar, each of said tone producing circuits including means for producing a tone signal corresponding to said key, means for varying the amplitude of said tone signals produced by said tone producing circuits in accordance with the amplitude of said transducer means signal, and means for applying said tone circuit tone signals simultaneously to said audio output means for producing a composite tone generator tone signal corresponding to said key.

9. The electronic piano of claim **7** including first sustaining means for sustaining the output of said electronic tone generator for a period of time after the release of said key by a player.

10. The electronic piano of claim **9** including a second sustaining means, said second sustaining means being operative to sustain the tone signal from said tone generator for a period of time greater than that of said first sustaining means.

11. The electronic piano of claim **10** wherein said key is biased to a released position, and key position sensing means for sustaining said tone signal for the same period of time as said second sustaining means so long as said key is in a depressed position.

12. The electronic piano of claim **11** wherein said key position sensing means is a switch operative by said key.

13. Electronic musical apparatus comprising key means, electronic transducer means for producing a signal in accordance with the force of the striking of said key, an electronic tone generator for producing a tone signal corresponding to said key means and for varying said tone signal amplitude in accordance with the amplitude of said transducer means signal, audio output means for producing an audio output in accordance with the output of said electronic tone generator, key position sensing means, said key position sensing means being operative in accordance with the depression of said key means to produce an output signal, said electronic tone generator being additionally sensitive to said position sensing means output signal to produce a tone signal corresponding to said key means, said last-mentioned tone signal being of a sustained amplitude.

14. The musical apparatus of claim **13** wherein said key means comprises a key operated action, said transducer means being associated with said key operated action for producing a signal in accordance with the force of the striking of said action key, said key means additionally including a second key, said position sensing means including contacts associated with said second key.

15. An electronic piano comprising a key operated, velocity sensitive transducer means for directly transducing the velocity of a struck key into an electric signal proportional thereto, a core element associated therewith, said velocity sensitive transducer means including a coil, means to move said core to vary the inductance of said coil in accordance with the velocity of said key, means for applying the electric signal to an electronic oscillator, and audio output means for producing an audio signal in accordance with the output of said oscillator.

16. An electronic musical apparatus comprising a key, an action responsive to a struck key, said action including a hammer and means to move said hammer in a predetermined path when said key is struck, a core element of magnetizable material mounted on said hammer, a velocity sensitive transducer including a coil aligned in the path of movement of said core element, whereby said core element may be moved adjacent said coil to change its inductance, electronic means responsive to changes in the inductance of said coil to develop a tone generator triggering signal, a tone signal generator responsive to said triggering signal to produce an output electric signal, said tone signal generator including an oscillator and a wave shaping circuit, and audio output means connected to said wave shaping circuit for producing an audio signal in accordance with said tone signal.

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Disclaimer

3,248,470.—*Jerome Markowitz*, Allentown, *Milton F. Nelson*, Macungie, and *Edwin H. Strain*, Allentown, Pa. ELECTRONIC PIANO HAVING MEANS RESPONSIVE TO THE VELOCITY OF THE ACTION. Patent dated Apr. 26, 1966. Disclaimer filed June 2, 1969, by the assignee, *Allen Organ Company*.

Hereby enters this disclaimer to claims 7 and 13 of said patent.

[*Official Gazette July 8, 1969.*]