

[54] **ELECTROPIANO**

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[51] Int. Cl. **G10c 3/04**

[58] Field of Search.....84/1.14, 1.16, 197, 209, 211,
84/214, 216, 217, 218

[56] **References Cited**

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3,049,958	8/1962	Benioff	84/1.16

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[57] **ABSTRACT**

An electropiano employing as a transducer rail one or relatively few strips of U-shaped aluminum extrusion between the arms of which are located a plurality of piezo-electric transducer elements separated from one arm by resilient damping pads located above metallic shims. The total number of transducer elements is about 25 percent of the number of tones, the transducers not being individual to the strings, but being acoustically coupled to the strings through the extrusion or strip. The strip is supported between the strings and a layer of resilient damping material which is located directly on the plate of the electropiano, and is secured only against gross lateral movement relative to the plate so that longitudinal acoustic vibrations along the length of the strip and flexural vibrations of the extrusion can occur. The transducer elements each have one electrode contacting an arm of the extrusion, which then provides a common electrical ground. The other electrode of each transducer contacts a conducting shim superposed on an electrical insulating and acoustical damping pad. These shims are connected to a common lead, so that all the outputs of a group of transducers may be applied to a common terminal. Damping means are provided just beyond the tuned segments of the strings, to provide tone diminution simulating that of a true piano.

14 Claims, 5 Drawing Figures

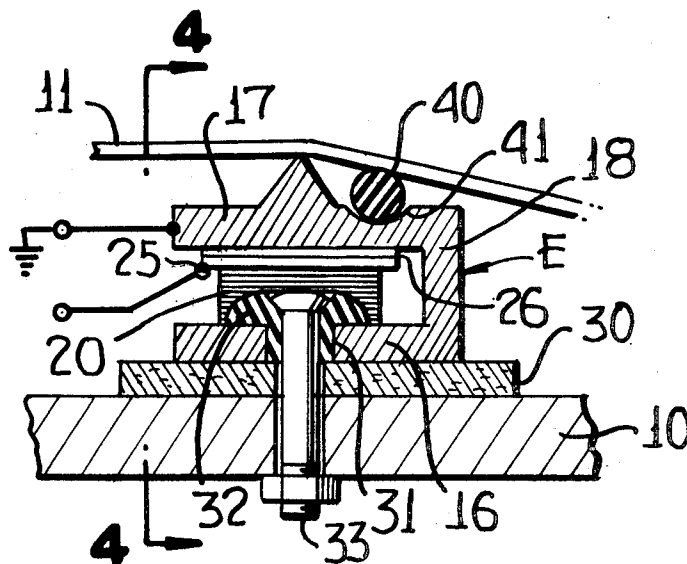


FIG. 1

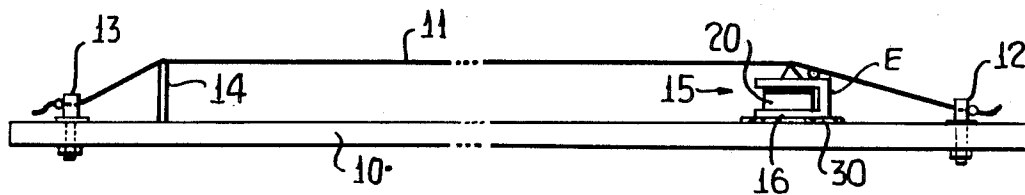


FIG. 2

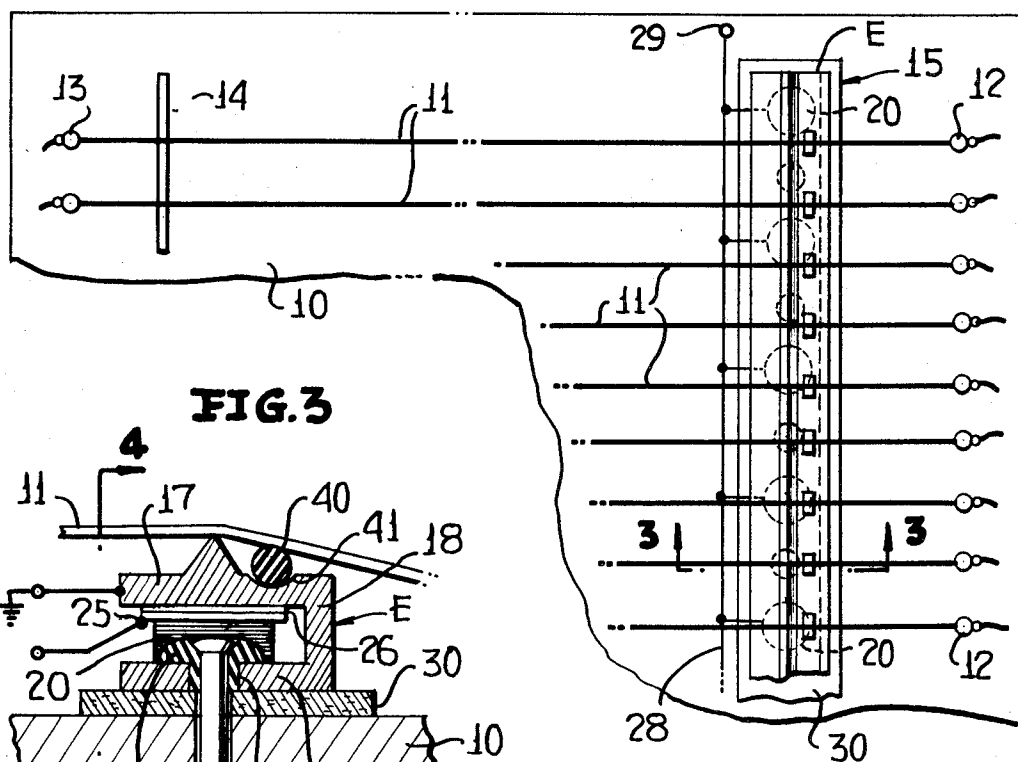


FIG. 3

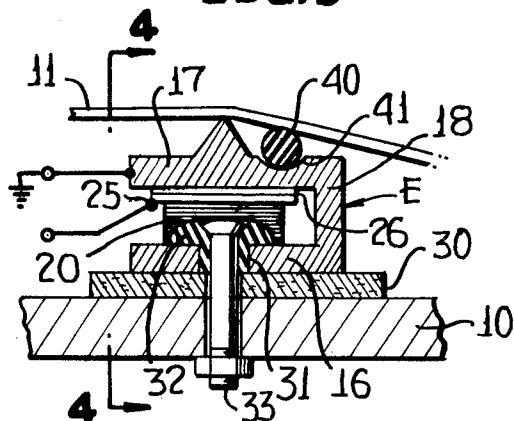


FIG. 4

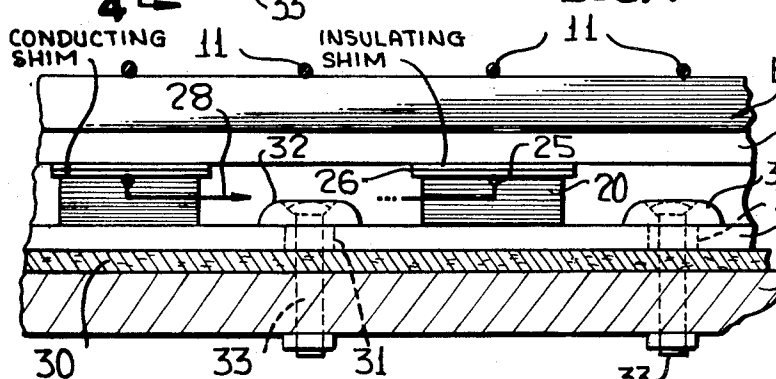
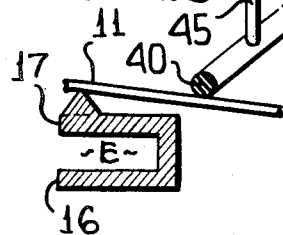


FIG. 5



ELECTROPIANO

This application is a division of our application, Ser. No. 714,888, filed Mar. 21, 1968, now U.S. Pat. No. 3,519,721, and entitled "ELECTROPIANO WITH PLURAL PIEZOELECTRIC PICKUPS ON UNITARY ACOUSTIC RAIL."

BACKGROUND OF THE INVENTION

The term, electropiano, as used herein means an instrument having a string plate, an action whereby the strings may be struck into vibration, but lacking a conventional bridge and soundboard, and having means whereby string vibrations may be converted into electrical pulsations, and these in turn into sound by means of a loudspeaker. Tones produced by an electropiano should closely resemble the tones of a conventional acoustical piano. Great difficulty has been experienced in achieving true piano tone quality in an electropiano, particularly because the bridge and soundboard of the acoustical piano strongly intercouple the strings of the instrument, and also control to a great degree the decay characteristics of the acoustical piano tones.

In an acoustical piano the strings are set into motion by the hammers of the action, which immediately after striking the strings are brought out of contact with them. Tone diminution is controlled by several factors, including string length, string coupling, termination impedance, and damping by the termination material and structure. When the dampers of a mechanoacoustic piano are raised, by the action of the sustaining pedal, considerable interaction among the strings representing notes of different fundamental frequencies occurs. The interplay among the strings is extremely complex, involving the numerous modes of vibration of each string, and accordingly gives the tone of an acoustical piano a recognizable quality. If this quality is not achieved in an electropiano the latter is not an optimum instrument.

Among the patents in the field which have sought to solve the problems above stated are:

Benioff, U.S. Pat. No. 3,049,958, which concerns itself with the design of transducers for individual electropiano notes and the production of suitable damping effects. The solution suggested was an improvement for individual tones but the damping and supporting structure used was at the expense of losing sympathetic vibrations in strings of adjacent and distant string groups. Neither did it adequately overcome the tendency for tones to run together when played in rapid sequence.

Martin and Ziegler application Ser. No. 553,335, filed May 27, 1966 and entitled Electropiano, shows solutions to these problems.

In the above instances and in various other electropianos it has been common to utilize a transducer for each string or group of strings producing a single note. The requirement of a transducer per note yields a relatively complex structure which is costly and difficult to keep in adjustment.

According to the present invention, a single cantilever transducer rail which can be fabricated, for example, by aluminum extrusion is utilized commonly for all the strings on the piano, although if desired for convenience in construction, two or conceivably three sections of such extrusions may be employed. In the latter case, the plurality is essentially both mechanically and

electrically the same as the single extrusion. By utilizing a single transducer rail for all the notes of the piano far fewer transducer elements may be employed than the number of tones of the piano. For example, in an 88-key piano, it is feasible to employ 20 to 25 piezo-electric transducer elements. Because all of the transducer elements are mounted in a common rail which is fabricated of metal and which is acoustically and structurally highly transmissive, coupling among the strings exists inherently, and vibration occurring anywhere along the rail is transmitted therealong to other strings.

The extrusion itself can be shaped to provide an edge on which the tuned segments of the strings terminate. Immediately beyond the tuned segment of the string and conveniently mounted directly on the extrusion can be provided a damping means for each string. This damping means is in the form of a dead rubber or plastic element in contact with the strings. The damping effect depends somewhat upon size, shape, density and hardness of the material.

The damping material can be distributed in individual pieces or for convenience of installation can be a continuous strip. It can be displaced toward or away from the end of the tuned segment to increase or decrease the diminution rate in accordance with the tonal needs in different pitch ranges. For ease of manufacture it is better to have a shallow trench in the extruded shape in which to position the damping material optimally. The different thicknesses, widths or diameters of the damping material are used to vary the damping rate in different ranges.

While the aforementioned method is ideal for adjusting fixed diminution rates for the strings of individual notes or ranges, it is also possible to provide easily within the same instrument, the option of either piano-like diminution rates or more sustained, organ-like tones, by an alternate mounting of the damping material. For this purpose the damping material is mounted on a special damper rod extending along adjacent to the transducer rail, with the rod mechanically biased by weight or spring to hold the damping material in contact with the string extensions for piano-like diminution rates. When more sustained tones are desired this rod is drawn away by pedal, manual or electrical control means, removing the damping material temporarily from contact with the string extensions.

The transducer rail provides better internote coupling and a more piano-like tone decay envelope if the rail is supported in a damped resilient manner relative to the rigid plate rather than being rigidly clamped to the plate. This in some ways resembles the Martin and Ziegler application mentioned above, but differs from it in that the transducer elements are within the rail structure. (In the Martin-Ziegler invention the elements were in individual-note transducers mounted upon a solid rail supported in a damped resilient manner.)

The theory of the action of the transducer rail and its support can be summarized in four parts, as follows:

1. The mechanical impedance match between the transducer rail and the strings (at a termination of their tuned segments) must resemble that of a conventional piano bridge, so that the transition from more rapid initial decay rate (for a group of initially in-phase strings) to less rapid terminal decay

rate (for strings later out of phase most of the time) is possible. This is achieved in the present invention by the combination of the cantilever profile, the resilience mechanically in series with the transducer elements, and the resilient support for the entire transducer rail relative to the rigid plate.

2. Moreover, at or near the termination of the tuned segments there must be additional mechanical damping to substitute for that of the wood in a conventional piano bridge, so that the overall tone diminution rate will be satisfactory. In the present invention this is provided by the damping material contacting the strings just beyond their terminations, either on the transducer rail or on a separate rod removable for special organ-like tonal effect.
3. Furthermore, internote coupling must occur, as it does with a conventional bridge supported upon a vibratile board, so that when the dampers are lifted from all strings (or alternatively in some pianos from a group of bass strings only) there will be substantial sympathetic vibration from nearby strings having similar modal frequencies, and to a lesser degree for distant strings. In the present invention this coupling results primarily from direct transmission through the continuous cantilever, and secondarily by flexure of the entire transducer rail as a result of its resilient (rather than strictly rigid) support upon the plate.
4. The tonal output of the transducer elements results from variable stress at audio frequencies between the faces of the elements. A fixed stress, provided by normal compression of the rail cantilever arm toward its base, secures the elements in place and insures that large amplitudes of vibration will not loosen the elements even momentarily. The damping pads between the elements and the rail prevent the rail from presenting too high a mechanical impedance to strings crossing at the elements, and help to equalize the output of the element for all strings in the immediate vicinity of the element. Both these damping pads and the damping material between the transducer rail and the plate prevent impact sounds in the rail and plate from having excessive duration.

SUMMARY OF THE INVENTION

An electropiano employing acousto-electro transducers smaller in number than the number of tones of the electropiano, the transducers being mounted identically in a continuous aluminum strip of U-shaped cross-section, the strip being so associated with the string plate of the electropiano that internote coupling and damping occur which closely imitate the string inter-coupling and damping which normally exists in a mechanical piano, so that true piano tone is closely simulated. Each string is provided with a damping surface located just beyond its tuned segment, which causes the string tone decay with time to simulate the decay curve of a true piano string.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in side elevation of a first embodiment of the invention;

FIG. 2 is a view in plan of the system of FIG. 1;

FIG. 3 is a view in section taken on the line 3—3 of FIG. 2;

FIG. 4 is a view in section taken on the line 4—4 of FIG. 3;

FIG. 5 is a partial view in section of a modification of the systems of FIGS. 1—4, inclusive, indicating a mode of varying the diminution rate of string vibration.

DESCRIPTION OF THE EMBODIMENTS

String plate 10 supports a plurality of stretched piano strings 11 between anchor pins 12 and tuning pins 13. Each string passing over an agraffe means 14 adjacent the tuning pins 13, and over a transducer assembly 15 adjacent the anchor pins 12. When strings are referred to they may involve one string per note, especially in the bass range of the piano, and three strings per note in the treble section. Or, as in the case in some electropianos, one string per note may be used throughout.

The transducer assembly 15 preferably comprises an elongated aluminum extrusion E, having a U-shape in transverse section, i.e., a base arm 16, a cantilever arm 17, and a short element 18 joining the base 16 to the cantilever arm 17 at one side only, leaving the remaining side of the extrusion open, as in the manner of a U lying on its side. A single extrusion may extend across all the strings, and acts as an agraffe element therefor, the instrument containing no bridge or sounding board. The extrusion may be subsequently curved to conform to the desired layout of termination points, or the transducer rail may be cast into a curved shape initially.

The transducer assembly 15 has about 20–25 transducer elements 20 for an entire piano, assuming 88 notes. The transducer elements 20 are distributed along the extrusion E such that the loudness of each separate note is appropriate to the loudness of that note in an acoustical piano. In this respect, bringing a transducer element closer to a string enhances its output in response to striking of that string.

The transducers 20 are preferably ceramic piezo-electric elements, and are provided with silver electrodes, and operate in the thickness mode. The lower electrodes of the piezo-electric elements 20 all impinge on the base arm 16, so that the transducer assembly provides a common ground for all the transducer elements. The upper electrodes of the piezo-electric elements 20 contact bronze shims 25, which in turn contact a layer of insulating rubber material 26, which is also acoustically damping. The shims are all connected together by a common lead 28, which proceeds to an output terminal 29. The base 16 rests on a layer of acoustic isolating material 30, e.g., felt, which acoustically isolates assembly 15 from the string plate 10, and assures that ringing of the string plate will not be communicated to the transducer assembly unduly.

The transducer elements 20, when assembled in an instrument, are under sufficient compression that ac signals are accurately transduced and that elements 20 are not loosened due to strong vibration.

Alternative types of transducer elements can be used within the U shaped transducer rail 15. For example the rail may be of soft magnetic material such as iron, and magnet coil transducers can be substituted for the ceramic elements 20 either with or without rubber dampers 26.

In order to locate the transducer assembly 15 with respect to the string plate 10, holes 31 are provided in the base 16, which are grommets loosely as at 32, and fit over pins 33 secured to the string plate. The cantilever arm 17 is thus left free, because the grommets are not rigid, to vibrate piezo-electric element 20, with respect to the base 16, and also to convey the vibrations longitudinally along its length to unstruck strings, which are set into vibration and provide electrical signals at their own resonance frequencies to the output terminal 29. This action simulates the action of the conventional acoustical piano very closely, except that in an acoustical piano interstring coupling occurs primarily via a bridge and soundboard, and in the present invention interstring coupling occurs via the transducer assembly. This also overcomes a defect which commonly is found in an electropiano, i.e., that the tonal decay characteristic is quite unlike that occurring in an acoustical piano. The latter has essentially a double rate of decay, involving a rapid rate of decay to a lower level, followed by a very slow rate of decay thereafter. Electropianos usually have had almost linear decay rates.

Also in accordance with the present invention a damper of dead rubber 40, in the form of a strip, or a separate piece of such material, one per string (or string group), is located under the strings, in contact therewith, just outside the tuned segment of the strings. A suitable location is on the cantilever element. To maintain the dead rubber damper 40 in position a depression 41 may be formed in the upper face of the cantilever 17, to which the damper 40 conforms generally in shape. This damping action simulates the string damping by the wood of the conventional bridge right at the termination of the tuned segments of the strings. If dampers 40 are right at the agraffe edge of the cantilever or along the tuned segments the damping is abrupt and more difficult to control.

In FIG. 5 is illustrated a modification of the system of FIG. 3, wherein the dampers 40 are mounted on a movable rod 45, so that they may be separated from and moved into contact with the strings 11, or so that adjustable pressures against the strings may be achieved. This provides variations from conventional piano tonal diminution rates.

While we have described and illustrated one specific embodiment of the invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a piano having strings and a string plate, agraffe means supporting said strings on said plate near one edge thereof, a series of anchor pins on said plate facing said agraffe means and located between said one edge and said agraffe means, said agraffe means including at least one transducer rail supporting said strings on said plate, and a series of strings stretched over said rail and connected to said anchor pins, in combination with a damping element located between said strings and said rail on the anchor pin side of said rail, and means for moving said damping element selectively into or out of contact with said strings.

2. In a piano having a string plate, agraffe means on said plate near one edge thereof, a series of anchor pins on said plate facing said agraffe means, said agraffe means including at least one transducer rail on said plate, and a series of strings stretched over said rail and connected to said anchor pins, the combination of damping means contacting said strings near said rail between said rail and said anchor pins, and means for selectively moving said damping means into and out of contact with said strings.

3. In an electropiano, the combination comprising, a first and second agraffe between which are stretched tuned segments of piano strings, at least one of said agraffes including a transducer rail extending transversely of said strings, and string vibration dampers contacting said strings immediately adjacent one of said agraffes and externally of said tuned segments, wherein the positions of said dampers and the composition and dimensions of said dampers are selected to provide vibration diminution rates of said strings selected in accordance with the pitch ranges of said tuned segments to simulate a wholly acoustic piano, and means for selectively moving said dampers relative to said strings.

4. The combination according to claim 3 wherein said means for selectively moving said dampers includes a relatively rigid member engaging at least one of said dampers.

5. The combination according to claim 4 wherein, said string vibration dampers are located above said strings.

6. The combination according to claim 5 wherein said rigid member is above said strings and is arranged to move at least one of said dampers toward and away from said strings.

7. In an electropiano, the combination comprising a first and second agraffe between which are stretched tuned segments of piano strings, at least one of said agraffes being secured to a metallic cantilever rail, said rail extending transversely of said strings and having a cantilever extending parallel with said strings, and string vibration dampers of dead rubber-like material contacting said strings immediately adjacent said at least one of said agraffes and externally of said tuned segments, wherein the positions of said damper longitudinally of said strings, and the composition and the dimensions of said dampers are selected to provide vibration diminution rates of said strings selected in accordance with the pitch ranges of said tuned segments to simulate a wholly acoustic piano.

8. The combination according to claim 7, wherein said dampers are clamped between said strings and said rail.

9. The combination according to claim 7, wherein said dampers are located externally of said strings and said rail.

10. The combination according to claim 9, wherein is provided means secured to said dampers for selectively moving said dampers with respect to said strings.

11. In an electropiano, the combination comprising a first and second agraffe between which extend tuned segments of piano strings, a metal rail supporting at least one of said agraffes, and string vibration dampers of dead rubber-like material contacting said strings immediately adjacent said at least one of said agraffes and externally of said tuned segments, wherein the posi-

tions longitudinally of said strings and the composition and the dimensions of said dampers are selected to provide vibration diminution rates of said strings selected in accordance with the pitch range of said tuned segments to simulate a wholly acoustic piano.

12. The combination according to claim 11, wherein said dampers are clamped between said strings and said rail.

13. The combination according to claim 11, wherein said dampers are located externally of said strings and said rail.

14. The combination according to claim 11, wherein is provided means secured to said dampers for selectively moving said dampers with respect to said strings.

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