May 21, 1963 M. CLARK, JR 3,090,272

DYNAMICALLY KEYED MUSICAL INSTRUMENT

Filed March 16, 1960 2 Sheets-Sheet 1

FIG-1

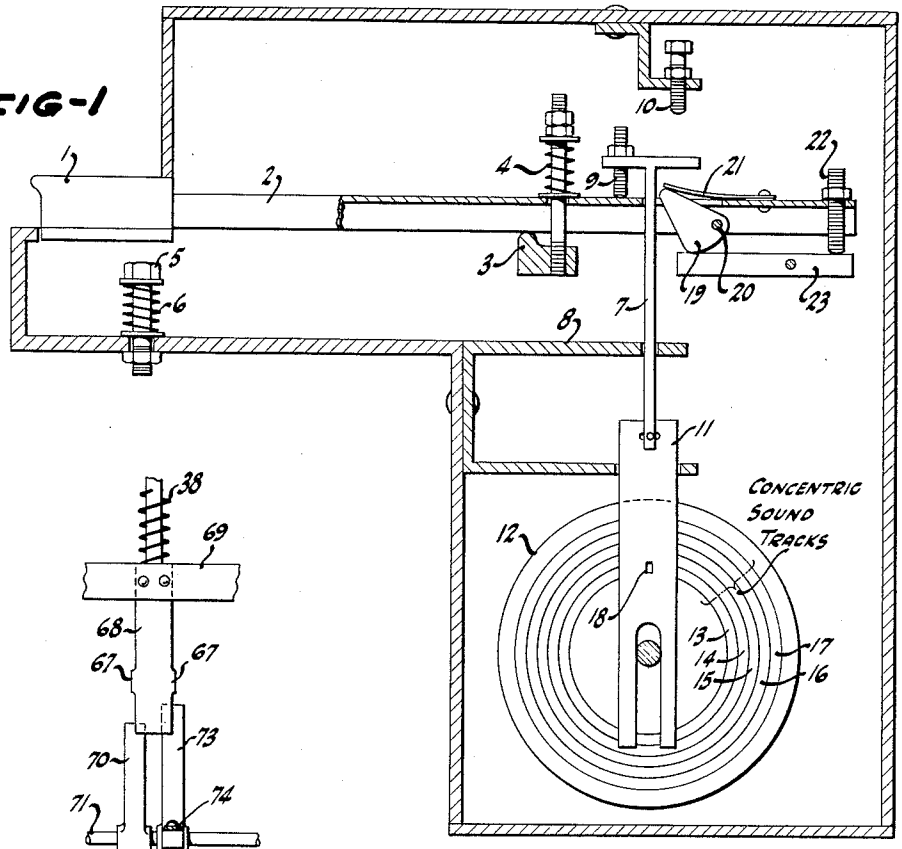


FIG-3

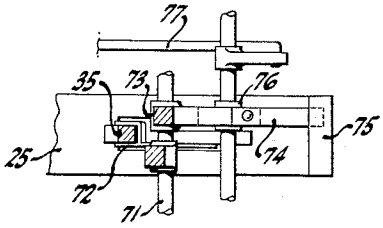


FIG-4

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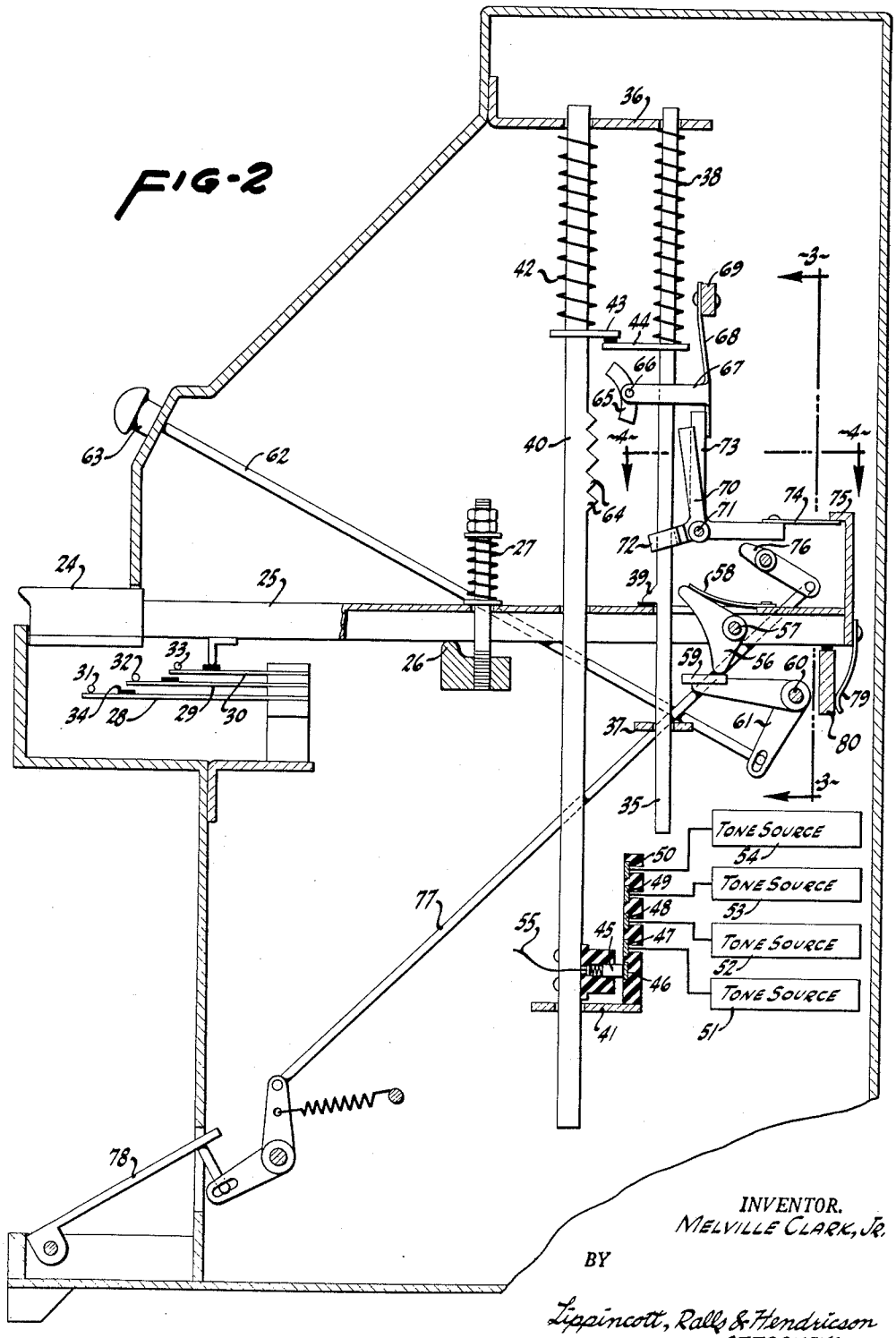
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Filed March 16, 1960 2 Sheets-Sheet 2

FIG-2



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United States Patent Office 3,090,272
Patented May 21, 1963

3,090,272

DYNAMICALLY KEYED MUSICAL INSTRUMENT

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Filed Mar. 16, 1960, Ser. No. 15,480
11 Claims. (Cl. 84—1.26)

This invention relates to keyboard electrical musical instruments, and its chief objects are these: to provide such instruments with touch-sensitive, dynamic keying whereby the character of the generated tone depends upon the force with which the playing key is struck and the resulting speed of depression of the key; to provide nuances controlled by variations in pressure applied to the key after its initial depression; and to provide an electrical instrument capable of generating rapidly-repeating percussive (slowly decaying) tones. This application is a continuation in part of my copending application Serial No. 543,949, filed October 31, 1955, now U.S. Patent No. 2,946,252, issued July 26, 1960.

Briefly, musical instruments according to this invention have a number of playing keys, at least one for each note, arranged in one or more keyboards, as in an organ, for example. Through suitable linkage to be described, these keys control a number of tone generators, each having a movable control part and each operating to produce an electric tone signal that varies in character—e.g., in amplitude or waveform, or both—depending upon the position of its control part. By way of example, the tone generators may be photoelectric, as disclosed in my copending application identified above, having a movable shutter as the control part, or the tone generators may be of the electrical network type described in my article "Keyboard Musical Instrument," published in The Journal of the Acoustical Society of America, April 1959, particularly at pages 407–408 including FIG. 7, having movable brushes as the control part.

The linkage between each key and control part includes at least first and second movable parts, with the second normally resting against the first so that movement of the first part responsive to depression of the playing key throws the second part a variable distance, depending upon the speed with which the key is depressed. The second or thrown part controls the tone generator, and thus the character of the generated tone is controlled by the force with which the key is struck. Additionally, the invention provides detents operable to hold the thrown part in a displaced position for as long as the key is kept depressed, provisions whereby further movement of the key after its initial depression can vary the tone character to provide nuances under the control of the player, and additional tracker and delay mechanisms enabling the production of rapidly repeating percussive-type tones.

The foregoing and other aspects of the invention may be understood better from the following illustrative description and the accompanying drawings.

FIG. 1 of the drawings is a somewhat schematic, vertical section showing a simple embodiment of the invention;

FIG. 2 is a somewhat schematic, enlarged vertical section showing a more elaborate embodiment of the invention;

FIG. 3 is an enlarged sectional detail taken along the line 3—3 of FIG. 2;

FIG. 4 is an enlarged sectional detail taken along line 4—4 of FIG. 2.

Referring to FIG. 1, there is shown one playing key and its linkage to a tone generator for playing a single note of the musical scale. The complete instrument comprises many such keys and linkages, the keys being preferably arranged in a keyboard, as in a piano or organ. Inasmuch as the provision of additional keys involves chiefly a duplication of parts, as will be clear to those skilled in the art, it is considered sufficient to illustrate and describe a single key and its associated linkages to a tone generator.

The playing key 1 is fastened to one end of a lever or key channel 2 (generally a steel bar of channel-shaped cross-section) mounted for swinging motion about a fulcrum 3. Thus channel 2 is a first movable part in the linkage operated by the playing key 1. An adjustable compression spring 4 urges the back end (the right-hand end as viewed in the drawing) of lever 2 downward, thus urging playing key 1 upward for returning the key to its rest position following the playing of a note. Downward motion of the playing key is arrested by a stop bolt 5, which preferably is resiliently mounted upon a prestressed spring 6 so that the key 1 may be depressed further, by the application of additional force, following its initial depression and bottoming upon the stop bolt.

A vertical bar 7, herein called a metering bar, or second movable part, is slidingly mounted within a slot of a guide plate 8 and a slot in the rear end of lever 2, so that bar 7 can move vertically. A portion of the bar, e.g., the adjustable screw 9, forms a downwardly facing shoulder, which normally rests upon the rear end of lever 2, whereby bar 7 is set into motion upwardly whenever playing key 1 is depressed. The metering bar, however, can continue its upward motion after the key bottoms on stop bolt 5, whereby the shoulder of the metering bar moves away from lever 2 and bar 7 continues to travel upward a distance that depends upon the speed of depression of key 1. In other words, when key 1 is struck lightly and thereby depressed slowly, bar 7 is lifted slowly and has little momentum when the playing key bottoms against its stop bolt. Hence, in this case, bar 7 is raised a relatively short distance: approximately equal to the distance that key 1 moves times the ratio of the two lever arms measured from fulcrum 3. On the other hand, when key 1 is struck more forcefully it is depressed more rapidly, considerable momentum is imparted to bar 7, and the metering bar travels upward a substantially greater distance. Maximum upward travel of the metering bar is limited by a stop, e.g., an adjustable screw 10.

The metering bar 7 is connected to raise the shutter 11 or control part of a photoelectric tone generator, which may be of the type more fully described in my copending application identified above. Briefly, the tone generator comprises a continuously rotating disc 12 carrying a plurality of concentric, variable-density sound tracks, identified by reference numbers 13 through 17, inclusive. Shutter 11 contains a small aperture or scanning slit 18, which uncovers the sound tracks successively, one at a time, as shutter 11 is moved upward. It will be understood that shutter 11 is illuminated with a light beam, so that light passes through the sound track uncovered by aperture 18 and is modulated by the variable density of the illuminated sound track as disc 12 rotates, and that the modulated light falls upon a photocell which converts it into an electric tone signal. Track 13 aligned with aperture 18 in the rest position of shutter 11 is unmodulated, e.g., opaque, and the remaining tracks are density-modulated with different musical tones, all of the same pitch but varying progressively in character, e.g., in amplitude or waveform or both.

For purposes of illustration and explanation, it will be assumed that tracks 14–17 are modulated with tones of progressively increasing amplitude (loudness), the loudest tone being that upon the outermost track, and that there are also progressive changes in waveform, e.g., an increasing harmonic content of the tone, as the loudness increases. Thus, as shutter 11 is raised by metering bar 7, the electric tone signal generated becomes progressively of greater amplitude and richer harmonic content. If playing key 1 is struck with sufficient force to throw metering

bar 7 upward as far as stop 10 permits it to go, aperture 18 will reach its uppermost position in alignment with track 17 and a tone of maximum amplitude or loudness will be generated. On the other hand, if key 1 is struck more gently, aperture 18 will be raised a lesser distance, say no further than alignment with track 15, and a tone of smaller amplitude will be generated.

For the production of sustained tones it is necessary that the metering bar 7 be held in the raised position to which it is thrown until the playing key 1 is released. A cam-shaped detent 19 is provided for this purpose. The detent or cam 19 is rotatively mounted upon a pin 20 attached to the keying channel 2 and is urged into contact with the side of bar 7 by a small leaf spring 21. The point of contact lies above pin 20 so that upward movement of bar 7 tends to release the pressure at the contact, whereby the detent offers little resistance to upward movement of metering bar 7. However, as soon as the metering bar starts downward the detent 19 stops such downward movement and holds bar 7 in a fixed, raised position relative to lever 2. Shutter 11 is likewise held in a raised position and thus the tone or note played can be sustained for any length of time that may be desired.

Upon release of playing key 1, the playing key and lever 2 are returned to their rest positions by spring 4. Thereupon a screw 22 attached to the keying channel strikes one end of a small lever 23, the other end of which engages the underside of cam-shaped detent 19 and rotates the detent to the released position (shown) slightly out of contact with the side of bar 7. Bar 7 can now fall to its rest position, and generation of the tone is terminated.

While the tone played is being sustained by holding playing key 1 down, the bar 7 and shutter 11 are not necessarily held absolutely stationary, but rather are held in fixed relation to the keying channel 2. This is important because it permits the production of nuances—variations in the character of the tone—by varying the pressure upon key 1. For example, if the pressure upon the key is increased, the key can move downward a bit more, compressing spring 6, and thereby shutter 11 can be raised a bit further and the tone produced can be made a bit louder; conversely, a decrease in pressure applied to key 1, without releasing the key entirely, will lower shutter 11 a bit and make the tone softer. Hence, the musician has great control over the tones that he is playing.

FIG. 2 illustrates a more elaborate and more versatile linkage and a different type of tone generator. Playing key 24, lever 25, fulcrum 26, and spring 27 are essentially like parts 1–4 of FIG. 1. In place of bolt 5 and compression spring 6, a plurality of leaf springs 28, 29, and 30 are provided for similar purposes. Each of these leaf springs is preloaded or prestressed by means of the three fixed pins 31, 32, and 33, which prevent the leaf springs from ever returning to a completely straight or unstressed position. Hence, as each spring is picked up by depression of key 24, there is an abrupt increase in the force necessary to depress the key further, and thereby a plurality of distinct, successive bottoming positions for the key are established. Felt pads (as at 34) may be provided to reduce unwanted noise.

The metering bar 35 performs functions similar to bar 7, FIG. 1, but is somewhat different in shape and mounting. Bar 35 is slidably mounted in slots through guide plates 36 and 37. The force of gravity acting upon the the metering bar is supplemented by a spring 38, which constantly urges the bar downward to its rest position. Bar 35 has a lug 39 forming a downwardly facing shoulder which normally rests upon key channel 25, whereby depression of playing key bar 24 sets bar 35 into motion upwardly. Because lug 39 can move away from the key channel when the momentum of bar 35 carries it upward, each operation of key 24 throws the metering bar 35 upward a distance that varies, depending upon the speed of depression of the key.

In this embodiment, the linkage between the metering bar and the tone generator comprises a second vertical bar 40, herein called the tracker bar, or third movable part, which is mounted for sliding, vertical movement parallel to bar 35. The tracker bar passes through slots in guide plates 36 and 41, through which it slides freely for vertical motion. It is urged downward toward its rest position by gravity and by a light compression spring 42. The bar 40 has attached thereto a crossbar 43 forming a downwardly facing shoulder which normally rests upon a crossbar 44 attached to bar 35. Hence, whenever bar 35 is thrown upward, bar 40 must be displaced upward by at least as great a distance, but when bar 35 returns to its rest position bar 40 does not necessarily follow immediately, as will be explained more fully hereinafter.

Connected to bar 40 and movable therewith is a brush 45, which is a movable control part of a tone generator which may be of the electrical network type described in my article identified above. Cooperating with brush 45 is a set of electrical contacts 46, 47, 48, 49, and 50, spaced apart and aligned so that brush 45 can touch each contact in succession as the brush is raised by upward movement of tracker bar 40. Contact 46, which the brush touches in its rest position, is not connected to a signal source. The other four contacts are respectively connected to four tone sources, 51, 52, 53, and 54, which may comprise different network connections as explained in the aforesaid article, or any other means for supplying to the several contacts electric tone signals of the same pitch but differing in character, e.g., amplitude or waveform or both. Hence, as the brush moves upward the output lead 55 connected to the brush is supplied an electric tone signal of progressively changing character. For purposes of explanation, it will be assumed that the signal supplied by sources 51 to 54 are of progressively greater amplitude (loudness) and progressively richer harmonic content, the loudest tone being supplied by source 54.

A cam or detent 56 is rotatively mounted upon a pin 57 attached to the keying channel, and is urged into contact with the side of metering bar 35 by a leaf spring 58. In the rest position of the playing key and keying channel, the bottom of detent 56 contacts a part 59 which turns the detent clockwise, releasing the grip of the detent on the metering bar, and thus permits the metering bar to return to its rest position after key 24 has been released following the playing of a note. Thus, detent 56 performs a function similar to that of detent 19 of FIG. 1. In the FIG. 2 embodiment, however, an additional provision is made: the part 59 is movable—e.g., it may take the form of a lever mounted upon an axle 60, which can be rotated through the additional lever arm 61, tie rod 62, and knob 63, to raise part 59 sufficiently that detent 56 is held out of contact with metering bar 35 even when key 24 is fully depressed. In other words, a means is provided whereby the player may, at will, eliminate the effect of cam 56 and permit metering bar 35 to return to its rest position as soon as its upward momentum is lost, without waiting for return of the playing key to rest position. This provision is of importance to enable the playing of rapidly repeating percussive-type tones, as will be more fully explained subsequently.

A rack-and-detent escapement is provided for delaying the return of tracker bar 40 to its rest position, for producing slowly decaying percussive-type tones. The rack of this escapement may consist of a plurality of teeth 64 formed on one side of tracker bar 40. The detent 65 is rotatively mounted for oscillation upon a pin 66 supported by a pair of arms 67 bent over from a leaf spring 68 supported by stationary frame member 69. Hence, the leaf spring 68 urges the detent into operatively cooperating relation with the rack, whereupon the detent must oscillate to allow successive teeth 64 of the rack to pass, in a manner somewhat similar to a watch escape-

ment, whereby the tracker bar **40** is lowered gradually and slowly by the escapement. However, the escapement may be released to allow rapid motion of the tracker bar, up or down, by pressing the lower end of the leaf spring **68** to the right as seen in FIG. 2, thereby moving the detent **65** away from and out of cooperating relation with the teeth **64** of the rack.

A lever **70**, rotatively mounted upon a shaft **71**, is provided with a U-shaped pair of spring arms **72**, which embrace opposite sides of metering bar **35** in frictional, dragging relation thereto, so that lever **70** is turned clockwise (as seen in FIG. 2) about shaft **71** whenever bar **35** starts to move upward, and is turned counterclockwise as bar **35** begins to move downward. The upper end of lever **70** engages the lower end of leaf spring **68** as the lever turns clockwise, and thereby disengages the escapement. Hence, when key **24** is struck, the escapement is released or made inoperative as bar **35** starts upward, and therefore is no impediment to rapid upward motion of bars **35** and **40** in unison. When bar **35** starts downward, lever **70** rotates counterclockwise and the detent **65** of the escapement moves into operative relation with teeth **64** of the rack, thereby delaying the downward motion of bar **40**, so that bar **40** is lowered in a slow, timed motion.

An L-shaped lever **73** is also rotatively mounted upon shaft **71**, so that its upper end may engage the lower end of leaf spring **68**. A leaf spring **74** is attached to the horizontal arm of lever **73**, and this leaf spring is picked up by a bracket **75** attached to the end of key channel **25** when the playing key and key channel return to their rest positions. Thus, lever **73** operates to disengage the escapement, and permit tracker bar **40** to return rapidly to its rest position, following release of the playing key **24**. However, this action may be overridden by rotating the sostenuto cam **76** connected, for example, through linkage **77** to pedal **78**. When pedal **78** is depressed, cam **76** moves upward under the horizontal leg of lever **73** and prevents clockwise rotation of lever **73**, spring **74** flexing sufficiently to make this possible. In this case the tracker bar **40** will continue its slow descent even after the playing key has been released.

With the parts in the position shown in FIG. 2, the instrument may be played in a manner quite similar to that shown in FIG. 1. When key **24** is depressed, bar **35** is thrown upward a distance that varies depending upon the force with which the key has been struck. Bar **40** is carried upward a similar distance, and this raises brush **45** by an amount depending upon the speed of depression of the playing key, whereby the desired tone signal is supplied to lead **55**. Detent **56** holds bar **35** in its elevated position so long as the playing key remains depressed, and of course this also holds up bar **40** and brush **45** to produce a sustained note.

Nuances may be had as hereinbefore explained in connection with FIG. 1.

A leaf spring **79**, attached to the rear end of key channel **24**, is in frictional contact with stationary frame member **80**, forming a friction brake which resists every movement of the playing key. This provides highly desirable Coulomb damping, overcoming the tendency of the player's finger to tremble while he is holding the key down against the opposing spring forces.

Upon release of the playing key and the return of key **24** and channel **25** to their rest positions, part **59** releases detent **56**, and bar **35** quickly returns to its rest position. The key channel being in its rest position, spring **74** has rotated lever **73** clockwise and thereby released the escapement, so that bar **40** can likewise drop quickly to its rest position and the tone or note is terminated.

If percussive-type tones are to be produced, knob **63** is pulled out, which raises part **59** so that detent **56** is held out of contact with bar **35** at all times. Now when playing key **24** is depressed, bars **35** and **40** are thrown upward as before, but bar **35** returns immediately to its rest position as soon as it has lost momentum. As bar **35** starts down, lever **70** is rotated counterclockwise, permitting leaf spring **68** to bring detent **65** into operative cooperation with teeth **64** of the rack. Lever **73** offers no appreciable resistance to this, because depression of the key has released spring **74**. Hence, the rack-and-detent escapement delays return of tracker bar **40** to its rest position, and bar **40** and brush **45** move downward slowly, producing a slowly decaying, percussive type tone.

If key **24** is struck again, bar **35** is in position to be thrown upward once more to a distance depending upon the force with which the key is struck, even though bar **40** has not yet returned to its rest position. However, as bar **35** approaches the end of its upward travel, it picks up bar **40** and carries it back up to the proper position corresponding to the speed with which the key **24** was last depressed. Thus, percussive-type tones may be produced in rapid succession without any objectionable "pumping" action, by which I mean a progressively increasing loudness which might occur if a less cleverly contrived linkage had been employed.

Upon release of the playing key **24**, it is evident that lever **73** will disengage the escapement and permit bar **40** to return quickly to its rest position, thereby terminating the tone, provided pedal **78** has not been depressed to rotate the sostenuto cam **76**. If pedal **78** is depressed, the escapement will not be released and the slowly decaying tone will continue even after the playing key **24** returns to its rest position.

It will be appreciated that the invention is not limited to the specific examples illustrated and described, and that numerous changes and modifications will occur to those skilled in the art.

What is claimed is:

1. In an electrical musical instrument, the combination comprising first and second movable parts, a playing key operatively connected to move said first part, said second part normally resting against said first part so that movement of the first part by said key causes said second part to move away from its normally resting position against said first part a distance that varies depending upon the speed of operation of said key, and tone generator means connected to said second part for generating an electric tone signal that progressively changes in character as said distance varies.

2. In an electrical musical instrument, the combination comprising a fulcrum, a lever mounted for swinging motion about said fulcrum, a playing key attached to one end of said lever, whereby depression of said key causes the other end of said lever to rise, a vertical bar, means supporting said bar for vertical movement, said bar having a downwardly facing shoulder normally resting against said other end of the lever so that depression of said key sets said bar in motion upwardly carrying its shoulder away from said lever a distance that varies depending upon the speed of depressing the key, and tone generator means connected to said bar for generating an electric tone signal that progressively changes in character as said distance varies.

3. The combination defined in claim 2, additionally comprising a detent connected between said bar and said lever to prevent downward motion of the bar relative to the lever, and means for automatically releasing said detent upon return of said key and lever to their rest positions, whereby said bar is held in a raised position so long as the playing key is held down, may be additionally raised by further depression of the key, and returns to its rest position following release of the key.

4. The combination defined in claim 3, additionally comprising a plurality of springs arranged to oppose de-

pression of said key, and means holding at least one of said springs in a preloaded position such that the spring is not picked up until the key is partially depressed said spring, when picked up, supplying a force opposing the depression of said key of sufficient magnitude to impede its motion.

5. The combination defined in claim 3, additionally comprising a friction brake connected to offer resistance to motion of said lever.

6. In an electrical musical instrument, the combination comprising first, second, and third movable parts, a playing key operatively connected to move said first part, said second part normally resting against said first part and said third part normally resting against said second part so that movement of the first part by said key sets the second and third parts in motion, said second part being movable away from first part and said third part being movable away from said second part, whereby each operation of said key moves the second part a first distance that varies depending upon the speed of operation of the key and the third part is moved a second distance that varies depending upon said first distance, means delaying the return motion of said third part so that the third part returns to its rest position more slowly than the first and second parts, and tone generator means connected to said third part for generating an electric tone signal that progressively changes in character as said second distance varies.

7. In an electrical musical instrument, the combination comprising a fulcrum, a lever mounted for swinging motion about said fulcrum, a playing key attached to one end of said lever, whereby depression of said key causes the other end of said lever to rise, first and second vertical bars, means supporting each of said bars for individual, vertical movement, said first bar having a downwardly facing shoulder normally resting against said other end of the lever, said first bar being movable upwardly carrying its shoulder away from said lever, whereby depression of the playing key throws said first bar upward a first distance that varies depending upon the speed of depression of the key, said second bar having a downwardly facing shoulder normally resting against said first bar, whereby said second bar is raised a distance that varies depending upon said first distance, delaying means for slowing the downward movement of said second bar, and tone generator means connected to said second bar for generating an electric signal that progressively changes in character as said second bar moves vertically.

8. The combination defined in claim 7, additionally comprising means for releasing said delaying means automatically upon return of said playing key to its rest position.

9. The combination defined in claim 7, said delaying means comprising a rack-and-detent escapement.

10. The combination defined in claim 9, additionally comprising a release lever having an arm in frictional engagement with said first bar, whereby upward motion of the first bar turns the release lever in one direction and downward motion of the first bar turns the release lever in the opposite direction, said release lever having another arm operatively engaging said escapement to separate the rack and the detent thereof as the release lever turns in said one direction, whereby said bars move upward together without interference by the escapement, and means returning said rack and detent into operatively cooperating relation as the release lever turns in said opposite direction.

11. The combination defined in claim 10, additionally comprising means for automatically separating said rack and said detent when the playing key returns to its rest position.

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