

[54] **MUSICAL INSTRUMENT PUSHBUTTON
KEY OPERATED SWITCH WITH
ADJUSTABLE PLUNGER KEY CAP**

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200/61.62, 200/172 A

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61.79, 61.89; 197/98, 102, 103, 107;
340/345 L; 29/453

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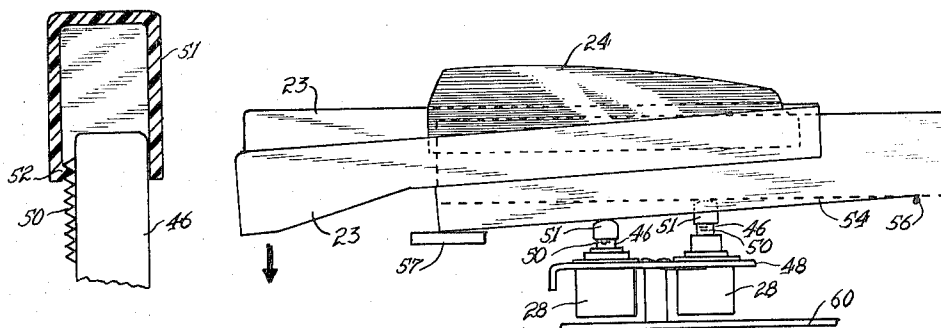
Primary Examiner—James R. Scott

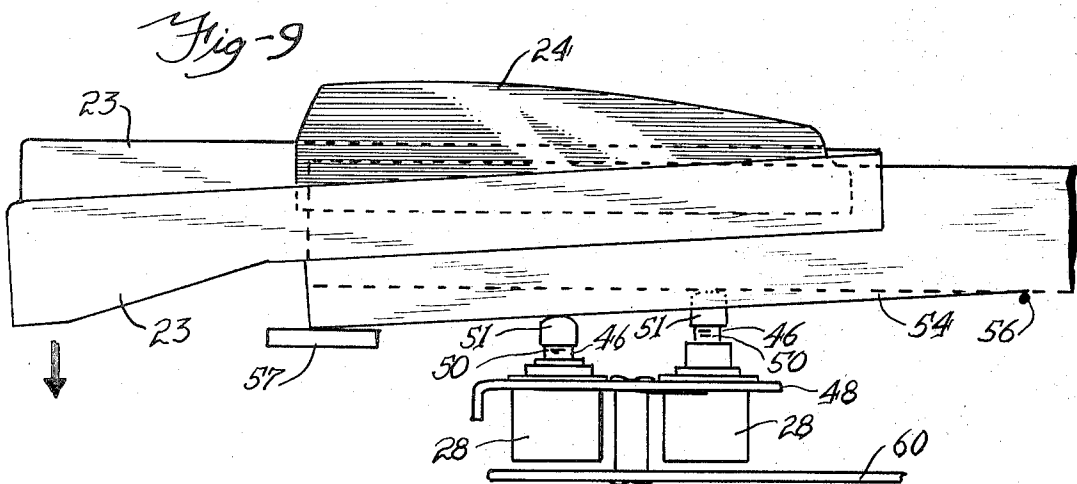
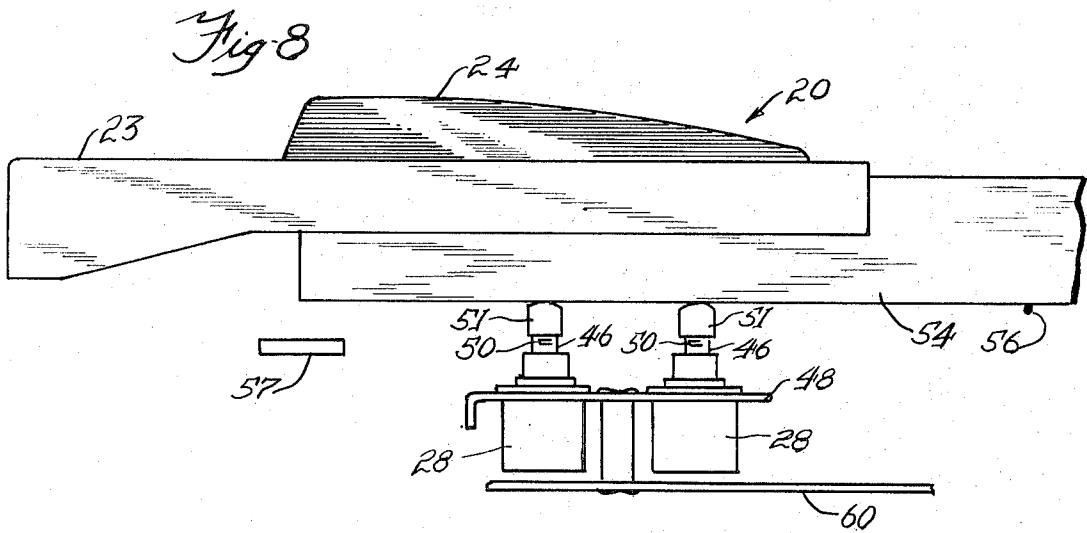
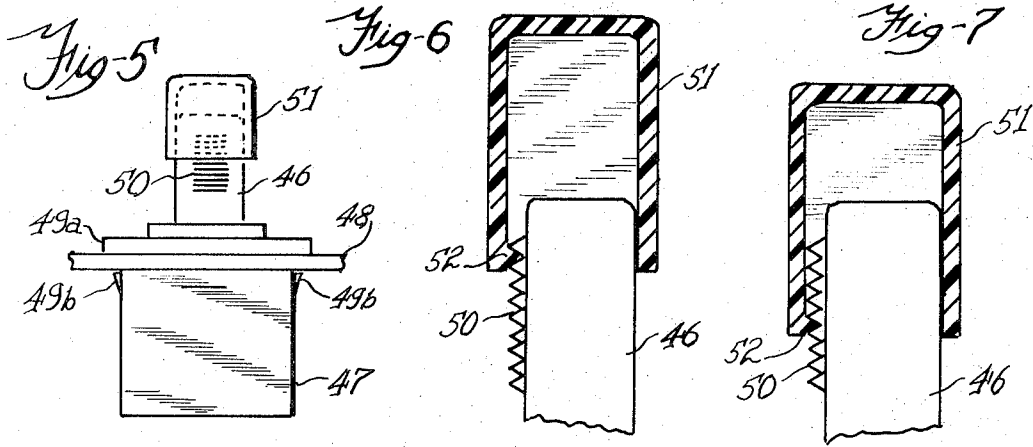
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[57] **ABSTRACT**

The embodiment of the invention disclosed herein is directed to a keyboard construction and electrical connection between a keyboard and its associated tone generators which electronically produce musical sounds. Each of the keys of the keyboard has associated therewith a switch structure which has a self-adjusting stem and stem cap which initially extends a distance greater than is ordinarily required during operation. When the keyboard is initially assembled, the first actuation of the key on the keyboard will depress the actuating stem and cause the stem cap associated therewith to ratchet to a final position where it will always remain. Each of the switches on the keyboard is wired into a matrix which forms part of an encoder logic circuit located at the keyboard. A second similarly constructed decoder logic circuit is associated with the tone generators located within the cabinet of the musical instrument. Time-frame encoding exists between the two logic circuits so that the logic circuit within the organ cabinet knows exactly when one of the keys on the keyboard is depressed to thereby enable the associated tone generator. Only a few wires are needed to interconnect the two logic circuits.

1 Claim, 14 Drawing Figures





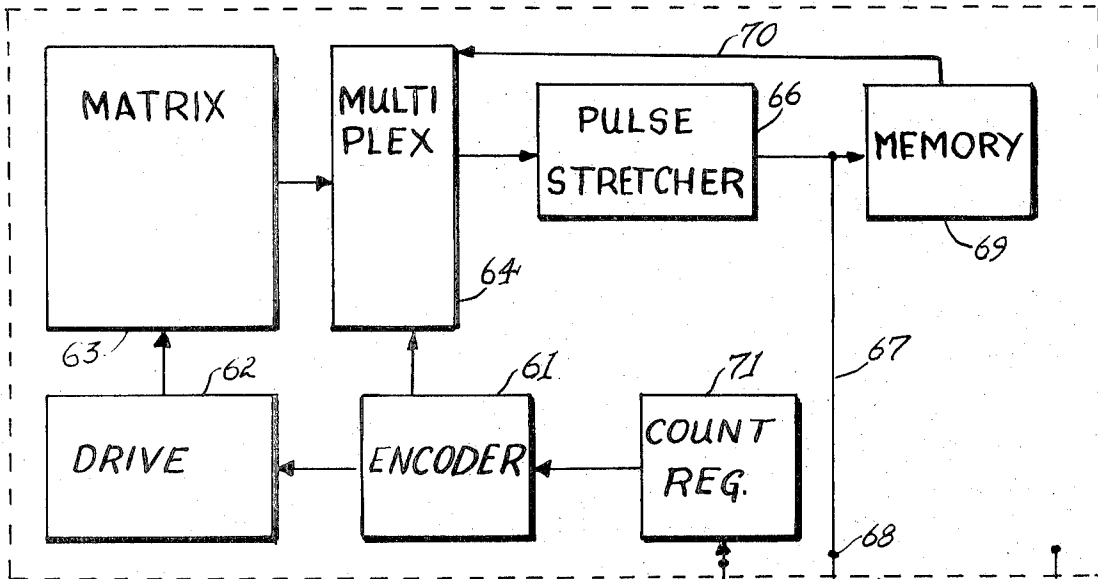


Fig-10

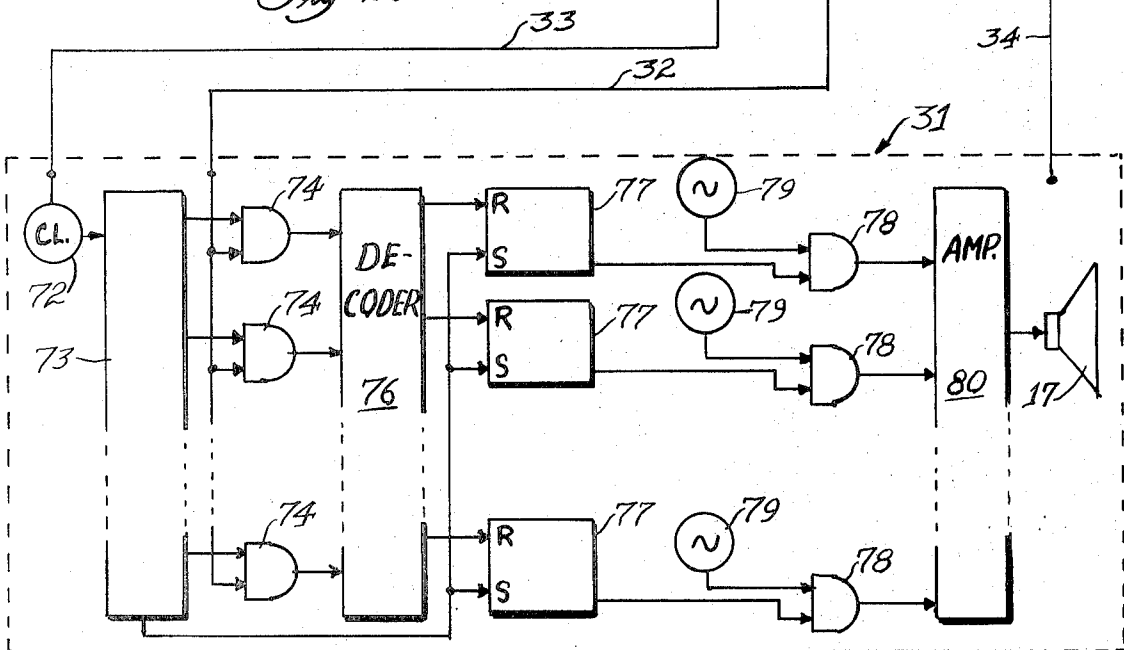
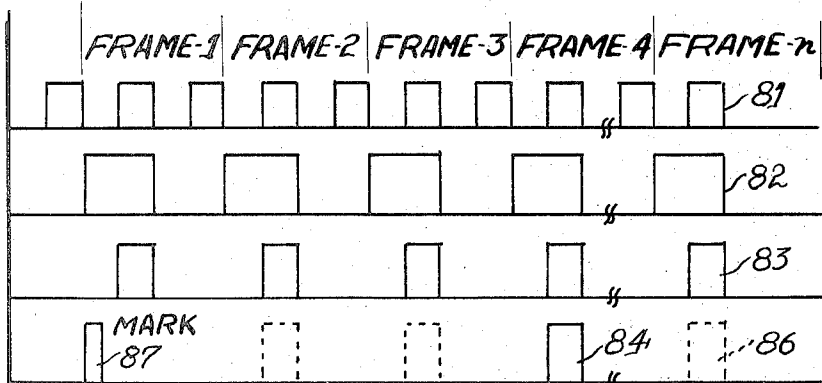
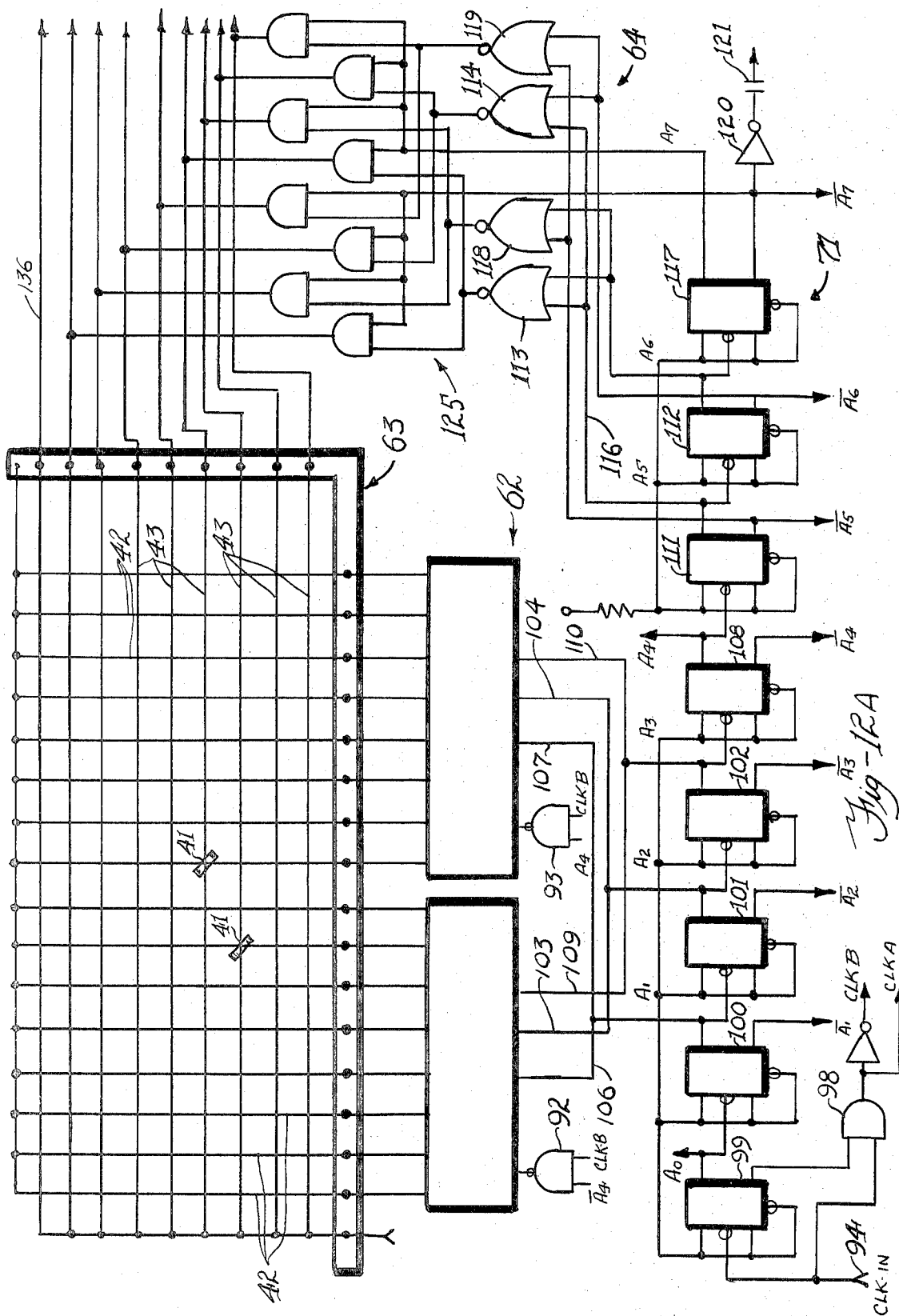
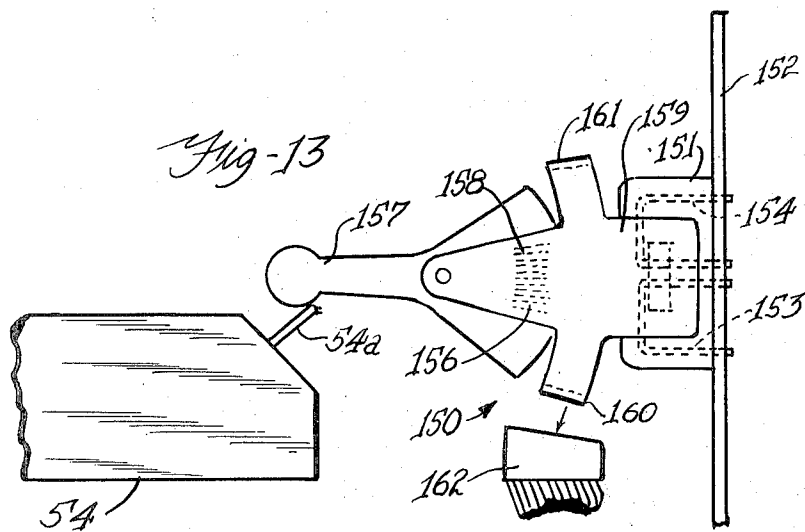
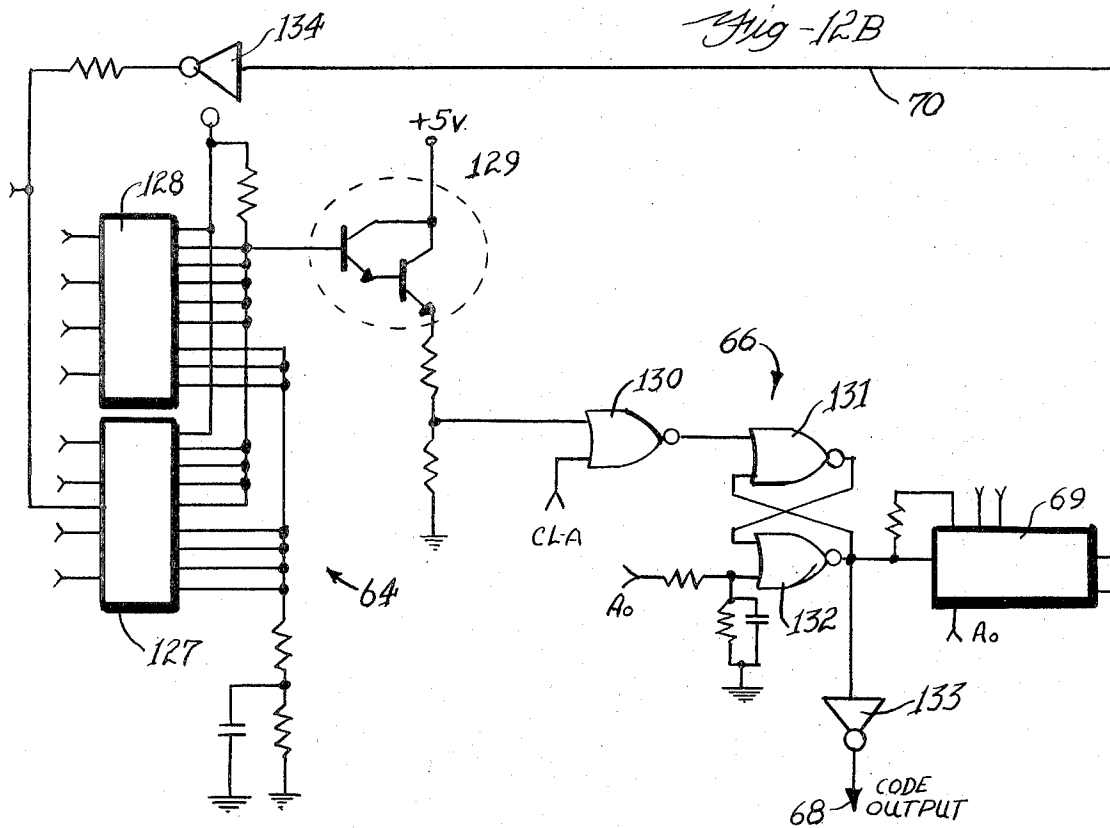


Fig-11







MUSICAL INSTRUMENT PUSHBUTTON KEY OPERATED SWITCH WITH ADJUSTABLE PLUNGER KEY CAP

BACKGROUND OF THE INVENTION

This invention relates generally to a keyboard construction and electrical interconnection for key actuated mechanisms and electrical responsive circuits, and more particularly to a keyboard construction and electrical interconnection for electrical musical instruments such as electronic organs, and the like. While the illustrated embodiment is directed to a keyboard construction for electronic organs it will be understood that the broad aspects of the invention as disclosed and claimed herein can be used in other fields without departing from the general concepts of this invention.

In the manufacture of keyboard instruments such as electronic organs, it is customary to interconnect a substantial number of wires between sub-assemblies such as keyboard switching mechanisms and a plurality of tone generator oscillators located within the cabinet proper of the electronic organ. This interconnection requires manual connecting, such as by soldering or the like, of a plurality of wires, one wire between each key and its associated circuit and tone generator. The customary keyboard switching device of prior art organs is a bus bar type connection with a switch contact formed on the key and engaging the bus bar when the key is depressed during playing. This causes an electronic signal to be delivered to the appropriate gate circuit to enable the tone generator. Because of the minimum space within the keyboard support structure, the tone generator and audio amplifier circuits are housed in the large rear portion of the cabinet which also houses such things as loudspeakers, foot pedal volume controls and the like. The interconnection of a plurality of key switches and a plurality of tone generators is a time consuming and expensive proposition, and even with experienced and skilled workmen doing the connecting operations there are sometimes inadvertent misconnections and bad solder joints which cause trouble with the finished product. For example, in a two-manual electronic organ having foot pedals, there may be as many as sixty-one keys for each manual position thus having a total of one hundred twenty-two (122) keys to be interconnected with one hundred twenty-two (122) different sounds produced by tone generators. The 122 wires providing this interconnection form a relatively large harness or sub-assembly which is mounted in the electronic organ cabinet with the terminating ends of each wire being fixed in position by soldering or the like. This type of interconnection greatly increases the cost of electronic organs because of the high cost of labor.

Another consideration when manufacturing keyboards for electronic organs is that adjustment of the bottom position of the key with respect to its actuating switch is necessary for each of the keys of the keyboard. This adjustment takes as long as two minutes in some instances and in a two manual organ having sixty-one (61) keys per manual, the adjustment time is in the order of about four hours. This also substantially increases the cost of electronic organs of the prior art.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to pro-

vide a new and improved keyboard structure which substantially eliminates the need for manual adjustment of each key.

Another object of this invention is to provide a new and improved circuit arrangement whereby the interconnection between a plurality of keys on a keyboard and a plurality of tone generators is accomplished with a minimum number of interconnecting wires.

A more specific object of this invention is to provide a new and improved electronic musical instrument which has a keyboard construction and electrical interconnection which is efficient and reliable in operation and simple and inexpensive to manufacture.

Briefly, the present invention relates to a switch and a switching system which has particular adaptation for electronic musical instruments such as organs and pianos. There are two physically spaced-apart logic circuits which rapidly scan a matrix switching arrangement associated with each of the keys on either a one or a two manual keyboard. The interconnection between the spaced-apart logic circuits is accomplished with as few as three wires, one for the clock generator signals, one for the output control signal in a given time-frame, and one wire for the interconnection of power between the electronic circuits. There is therefore no need for interconnection of each switch of the keyboard with its corresponding tone generator as this is now accomplished by proper timing of the encoder and decoder logic circuits.

The matrix arrangement disclosed herein has capabilities of 128 matrix points and is therefore well suited for use in a two manual keyboard arrangement having 122 keys. The clock pulse generator will produce a series of clock pulses, the first one of which is termed a mark pulse and each pulse thereafter representing a given time-frame position. The two spaced-apart logic circuits are therefore operated in unison with one clock pulse generator so that each time-frame position at the spaced-apart logic circuit represents whether or not its associated key at the keyboard is depressed. If a key is depressed, a pulse is generated into that time-frame and transmitted along a single wire to the second computer in the electronic organ cabinet. This second computer then energizes a tone generator circuit associated with that particular time-frame to produce the audio signal desired. The mark pulse which initiates each cycle of operation can be generated from a reset signal which may be located in a different place within the time-frame than all of the other pulses so that at the completion of a count of 128 pulses the restart or mark pulse will reset all of the logic circuits to an initial condition regardless of their state.

The other aspects of this invention is the incorporation of a mechanical switch structure which allows automatic adjustment of the switch with respect to the associated key, this automatic adjustment taking place upon the first manual actuation of the key. The particular switch disclosed herein is of the solid state type having a magnetic toroidal core structure through which passes two or more wires. One of the wires is a drive wire and another wire a sense wire so that signal coupling between the drive and the sense wire occurs only when the saturated state of the toroidal magnetic core is removed. The magnetic state of the toroidal magnetic core changes when the switch stem is actuated. A unique stem and ratchet arrangement is provided for each switch so that when the key of the keyboard is de-

pressed to a bottom or end of travel position it will drive the stem cap along its ratchet to an end position where it will at all times remain on the stem and move therewith. This therefore, eliminates the need for manual adjustment and substantially reduces the time to set up the keyboards after they have been assembled.

Many other features, objects, and advantages of this invention will be more fully realized and understood from the following detailed description when taken in conjunction with the accompanying drawings wherein like reference numerals throughout the various views of the drawings are intended to designate similar elements or components.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of an electronic organ incorporating the new and improved keyboard switch and electronic circuitry of this invention;

FIG. 2 is a diagrammatic representation of a solid state switching device used in the keyboards of FIG. 1;

FIG. 3 is an operative position of the solid state switch shown in FIG. 2;

FIG. 4 is a fragmentary top view of one of the keyboards shown in FIG. 1 illustrating the position of the solid state switches utilized herein;

FIG. 5 illustrates a switch structure utilizing a self-adjusting cap in accordance with one aspect of the present invention;

FIG. 6 is an enlarged fragmentary view showing the initial position of the self-adjusting cap on the switch of FIG. 5;

FIG. 7 illustrates the final bottomed position of the self-adjusting cap of FIG. 6 after an initial actuation;

FIG. 8 illustrates the relative position of the switches with respect to their keys prior to self-adjustment;

FIG. 9 illustrates depression of a key and adjustment of the stem cap of the associated switch;

FIG. 10 is a block diagram illustrating the basic components of the spaced-apart logic circuits for control between the keys of the keyboard and their associated tone generators;

FIG. 11 illustrates a time sequence of pulses to show the operation of a time-frame encoding system;

FIGS. 12a and 12b illustrate the detailed logic circuits in accordance with this invention; and

FIG. 13 is an alternate form of a switch constructed in accordance with this invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Now referring to the drawings, FIG. 1 illustrates an electronic musical instrument 10 wherein a novel switching structure and arrangement is utilized in accordance with the principles of this invention. The electronic musical instrument 10 is here shown as a two-manual organ which comprises a cabinet 12 having a keyboard portion 14 and a speaker portion 16 arranged in a well-known configuration. A speaker 17 is positioned at the front of the speaker portion 16 and is operatively connected to an amplifier and tone generator circuit arrangement generally shown by reference numeral 18. The tone generator and amplifier may be any one of a plurality of well-known types used to produce melodic tones in response to manual manipulation of the keys located at the keyboard portion 14.

The keyboard portion 14 has first and second keyboards 20 and 22 shown for the two-manual organ. However, it will be understood that a single keyboard can be incorporated when the invention is used in a single keyboard electronic organ or piano, or the like. The keyboard 20 has a plurality of natural keys 23 and a plurality of sharp keys 24 arranged in the usual piano keyboard configuration. Similarly, the keyboard 22 has a plurality of natural keys 26 and a plurality of sharp keys 27 also arranged in the piano keyboard configuration. This general configuration is illustrated in FIG. 4 which shows a fragmentary portion of the keyboard 20.

In the usual manner, prior art electronic musical instruments required a wire connection between each of the keys of the keyboard and its associated tone generator or tone generator gate circuit. This makes it necessary to use a relatively large complicated wire harness for their interconnection.

In accordance with the present invention, a solid state mechanism 28 is associated with each of the keys and connected in a matrix circuit of the "X-Y" array configuration which forms part of an encoder logic circuit 30. Spaced from the keyboard is a decoder logic circuit 31 which is operatively coupled to the amplifier and tone generator circuit 18. When one of the keys on either of the manual keyboards is depressed, a particular cross over juncture of the "X-Y" array causes an output signal to be developed from an associated solid state switch 28 and delivered over a line 32 to the decoder 31. This output signal corresponds to a time-frame encoding arrangement which will energize an associated one of a plurality of tone generators so that a sound can be electronically produced in response to actuation of a particular one of the keys on the keyboards. This output pulse travels over the single wire 32 and identifies any one of the plurality of keys on either of the keyboards. To maintain synchronization of the encoder 30 and the decoder 31, a clock pulse is delivered to both simultaneously over a line 33, and the clock generator can be located at either location. Because of space limitation, it may be desirable to place the clock generator at the decoder 31. Power is delivered to the encoder and decoder over a line 34. Therefore, instead of having the usual one hundred twenty-two (122) cables connected between the keyboards 20 and 22 and the tone generator circuits 18, only three wires are now needed to operate the electronic musical instruments.

While most any type of switching mechanisms can be used in accordance with the principles of this invention, the preferred switching device is a solid state switch as illustrated in FIGS. 2 and 3. The basic concepts of this switch are shown in U.S. Pat. No. 3,638,221. The operational theory of the solid state switch incorporated in the keyboards disclosed herein utilizes a U-shaped magnetic support member 36 having a pair of spaced-apart legs 37 and 38. Mounted to the lower ends of the legs 37 and 38 are a pair of magnets 39 and 40, respectively, which are diametrically opposed and on opposite sides of a magnetic toroidal core 41. Passing through the magnetic toroidal core 41 are in a pair of conductive wires 42 and 43, one of which is a drive line wire and the other of which is a sense line wire. When the magnets 39 and 40 are positioned as shown in FIG. 2, the magnetic toroidal core 41 is in a magnetically saturated condition. Therefore,

pulse signal information which is delivered along the drive line 42 will not be transformer coupled to the sense line 43 as a result of the magnetically saturated condition of the core. However, when the U-shaped magnetic support member 36 is depressed as shown in FIG. 3, this displaces the magnets 39 and 40 to unstatu-
rate the magnetic core and allow pulse signal information to be transformer coupled from the drive wire 42 to the sense wire 43.

Each of the U-shaped magnetic support members 36 has extending therefrom a switch stem 46 which is engaged with the key stick of its associated key of the keyboard to be depressed when the key is actuated. The particular physical configuration of switches can vary without departing from the scope of this invention, and one form may be that as shown in FIG. 4. Here a plurality of switches 28 are aligned in a row immediately beneath the natural keys 23 while a second plurality of switches 28 is aligned in a row beneath the sharp keys 24. While the switches are here shown as being immediately beneath the keys, these switches can be placed behind the key sticks and actuated by the key stick or by an actuating extension lever extending therefrom as shown in FIG. 13. The arrangement of the switches 28 and their associated toroidal cores 41 may be similar to that as set forth in a Bernin application Ser. No. 259,209, filed June 2, 1972, and assigned to the same assignee.

Referring now to FIG. 5 the details of construction of one of the switches 28 is shown having certain features which will allow for automatic adjustment of the length of the switch stem. Here a switch body 47 is inserted through a support plate 48 and firmly held in position by spaced-apart flange members 49a and 49b. Formed along the switch stem 46 is gripping means 50 preferably being closely spaced teeth-like members as best shown in FIGS. 6 and 7. However, it will be understood that the gripping means 50 can take other forms to achieve the same function. A stem cap 51 is positioned over the stem and arranged to engage the gripping means at the end most position along the stem so its initial length is longer than need be. When the switch is mounted in position under its associated key and actuated by depressing the key, the stem and stem cap will travel downwardly until the switch actuating mechanism within the switch body 47 bottoms. Once this bottoming action occurs further travel of the associated key will cause the stem cap 51 to automatically ratchet or move along the gripping means 50 to its final position as shown in FIG. 7. Thereafter when the key is actuated the switch will travel to its bottom position without resistance and without causing overtravel of the switch mechanism which would otherwise tend to increase switch wear.

To better understand the automatic adjustment feature of the switch stem and stem cap in connection with its associated key on a piano type keyboard reference is now made to FIGS. 8 and 9. Here a plurality of key sticks 54 are associated with each of the keys 23 and 24. Positioned beneath the row of key sticks 54 is the support plate 48 upon which is mounted a plurality of switches 28. The key sticks are pivotally secured to means, not shown, at a pivot point 56 in a well known manner so that depression of the end of the key, as shown in FIG. 9, will cause pivotal movement of the key about the pivot point 56. The actuating mechanism within the switch housing will bottom to stop further

travel thereof and the stem cap 51 will be ratcheted or urged along the gripping surface 50 to a height which corresponds to the bottom position of the key stick 54. The amount of travel of the stem cap 51 is determined by the distance between the key stick 54 and an associated stop member 57. When the key is released spring means will pivot the key stick about the pivot point 56 to its upper position and spring means within the switch housing will raise the stem 46 and stem cap 51. The overall length of the stem and stem cap is now permanently fixed for all subsequent actuations of the key and bottoming of the key and key stick will occur simultaneously with bottoming of the switch so that the same actuating characteristic is obtained for each manual manipulation. This then also allows uniform keyboard feel to the player of the electronic musical instrument. Mounted below the switches 28 may be a printed circuit board structure 60 which has mounted thereon the matrix and encoder circuit in accordance with the principles of this invention.

Referring now to FIG. 10 a general block diagram of the novel circuit arrangement utilized in accordance with this invention is illustrated. Also to be considered at this time is the waveform configuration of FIG. 11. Here the logic circuit 30 comprises an encoder 61 having an output line thereof coupled to a drive circuit 61, which, in turn, is connected to a matrix network 63. Preferably the matrix of network 63 is of the "X-Y" configuration having a plurality of cross line junctures which represent specific points to be electrically scanned. The output of the matrix 63 is coupled to a multiplex circuit 64 so that a pulse signal corresponding to an output of one of the junctures of the matrix can be delivered to a pulse stretcher circuit 66. This output signal is then delivered over a line 67 to a terminal 68 which connects the output line 32 between the two logic circuits 30 and 31. It will be recalled that the logic circuit 31 is at a remote location relative to the logic circuit 30 which is positioned next to the keyboard arrangement.

The matrix 63 and multiplex unit 64 together with the other components of the logic circuit 30 may conform substantially to that disclosed in application Ser. No. 339,476, filed Mar. 8, 1973, which is a continuation of application Ser. No. 144,902, filed May 19, 1971, now abandoned.

In accordance with this invention a memory circuit 69 receives the output pulse from the pulse stretcher 66 and provides a feedback connection over a line 70 to the multiplexer 64. This feedback forms a hysteresis loop to eliminate extraneous pulse signals from the matrix circuit.

The encoder 61 is driven by a count register circuit 71 which receives clock pulses over the synchronizing line 33. The clock generator circuit is located in the logic circuit 31 it being understood that it can also be located in the logic circuit 30. A clock pulse generator 72 is therefor coupled to the count register 71 and to the count register 73 which forms part of the remote logic circuit 31.

The output of the count register 73 is delivered to one of the inputs of the plurality of AND gates 74 which have the other inputs thereof coupled to the output line 32 to receive the time-frame coded output signal. Therefore as the AND gate 74 is scanned one at a time as a result of energization by the count register 73 the particular output pulse associated with a given

time-frame will actuate only one of the AND gates 74, this AND gate being associated with a particular one of the plurality of keys at the keyboard. This output signal is then delivered to a decoder circuit 76 which is driven in time sequence with the encoder 61 so that a particular one of the plurality of flip-flop circuits 77 is energized. This will set one of the inputs of a plurality of AND gates 78 to allow passage of an electronically generated tone from a particular one of a plurality of tone generators 79. This tone generator signal is then delivered to an audio-amplifier circuit 80 which, in turn, is operatively connected to the speaker 17 for energizing the same.

FIG. 11 illustrates the spacing between clock pulses 81 which controls operation of the count registers 71 and 73. The output of the pulse stretcher as shown by the waveform 82, and the scanned pulse as shown by the waveform 83. The output pulse corresponding to the actuation of a switch is shown at 84 while the output pulses which do not appear are shown in phantom lines at 86. A marked pulse 87 illustrates the beginning of a given cycle.

Referring now to FIGS. 12A and 12B a detailed block diagram of the logic circuit 31 utilized at the keyboard is illustrated. Here it can be seen that the matrix 63 comprises a plurality of "X" lines coupled to a pair of "X" line scan decoders 90 and 91 which comprise part of the decoder circuit 61. Coupled to the "X" line scan decoders 90 and 91 are NAND gates 92 and 93 respectively to synchronize actuation of each of the output lines thereof in a sequential manner. The input signal from the clock 72 is delivered to an input terminal 94 which may pass through a pair of series connected inverter amplifier circuits which has the output of one of them coupled first to a NAND gate 98 and then to an input of the first flip-flop circuit 99. The flip-flop circuits illustrated herein are of the "JK" type, it being understood that other flip-flops of the toggle configuration can be used.

The output of flip-flop circuit 99 is coupled to a second flip-flop circuit 100 which, in turn, is coupled to a flip-flop circuit 101. The flip-flop circuit 101 is connected to a flip-flop 102 and to a pair of lines 103 and 104 which are inputs to the "X" scan decoders 90 and 91. The output of flip-flop circuit 100 is also connected to a pair of input lines 106 and 107 which are also inputs to the "X" scan decoders. The output circuit of flip-flop circuit 102 is coupled to the input of a flip-flop circuit 108 and to a pair of lines 109 and 110 coupled to the input of the "X" scan decoders 90 and 91, respectively. This then will provide logical sequencing of the "X" lines of the matrix one at a time from, for example, the first line on the left to the last line on the right, or in the other direction if desired. To scan the "Y" lines of the matrix 63 the output of the flip-flop circuit 108 is delivered to still another flip-flop circuit 111 which, in turn, is coupled to a flip-flop circuit 112 and to a pair of NOR gates 113 and 114 over a line 116. The output of flip-flop circuit 112 is also connected to a flip-flop circuit 117 and to one of the inputs of the NOR gate 113 and to a NOR gate 118. A fourth NOR gate 119 has one input thereof coupled to the low state output of flip-flops circuit 113 and the other input thereof coupled to the low state output flip-flop circuit 111. When flip-flop circuit 117 is energized it completes the sequence of one cycle to produce a mark

pulse output through a pair of series coupled inverter circuits 120 and 121.

To control sequential energization of the "Y" lines of the matrix a plurality of AND gates designated as a group by reference numeral 125 are intercoupled with NOR gates 113, 114, 118, and 119 so that the eight "Y" lines are energized one at a time while 16 "X" lines are scanned during each energization of a "Y" line. In other words, a "Y" line is set to a high state or energized while all of the 16 "X" lines are scanned. This operation repeats until all of the "Y" lines are scanned and then the first "Y" line is again scanned to restart the cycle. This restarting of the scanning of the "Y" lines will produce the mark pulse, as shown at 87 in FIG. 11, necessary for each cycle of operation. The plurality of AND gates 125 and the NOR gates connected thereto form a part of the multiplex circuit 64 together with a pair of amplifier integrated circuit units 127 and 128 of FIG. 12B. The signal produced as a result of depressing one of the keys which has its associated switch at the juncture of the "X-Y" lines will be amplified through these amplifiers and delivered to a summer and buffer amplifier circuit 129. The output of the buffer amplifier 129 is delivered to a NOR gate 130 which forms a threshold detector so that only pulse signals of a predetermined amplitude will be delivered to the pulse stretcher 70.

The pulse stretcher 70 is formed by a pair of cross-coupled NAND logic circuits 131 and 132 to produce the output pulse to be delivered to the terminal 68 through an inverter circuit 133. The serial memory circuit 69 is coupled back to the amplifier circuits 127 and 128 over the line 70 through an inverter circuit 134 so that a cancellation signal can be applied to a cancel line 136 associated with the matrix. This cancel line eliminates the possibility of extraneous transformer coupling of signals from the drive line to unselected sense lines.

A modification of the switching arrangement in accordance with this invention is illustrated in FIGS. 13. Here an alternate embodiment of the automatic adjustment of the actuating plunger or lever is incorporated in a switch designated generally by reference numeral 150. The switch 150 includes a switch body 151 connected to a printed circuit board 52 by having the drive lines 153 and sense lines 154 connected to the printed circuit board by soldering of the end terminals inserted therethrough. The "X-Y" array of the matrix may be formed on the back of the printed circuit board.

An arcuately shaped gripping member 156 is formed along a lever 157 so that a tooth portion 158 of a magnet carrier 159 can move relative thereto when the magnet carrier reaches its stop position. To achieve this a pair of diametrically opposed stop members 160 and 161 are provided so that the switch can be inserted in either orientation. A stop portion 162 is positioned below the switch so that when the key stick 54 is raised, by depressing its associated key cap, it will raise the lever 157 to pivot the magnet carrier 159 downwardly until it engages the stop 162. Once the stop member 160 engages the stop 162 further travel of the key stick 54 will cause a ratcheting action between the gripping portion 156 and the teeth 158. This will cause the relative angular position between the lever 157 and the magnet carrier 159 to change so that when the key is bottomed by a full depressing action so also is the switch actuating mechanism engaged with its stop.

While several specific embodiments of the invention have been illustrated herein it will be understood that variations and modifications may be effected without departing from the spirit and scope of the novel concepts disclosed and claimed herein.

The invention is claimed as follows:

1. A keyboard construction for electronic organs comprising a manually operated key operatable about a pivot point to move from a first orientation to a second orientation upon actuation of said key, a stop means for stopping said key at said second orientation, an electric switch associated with said key having a depressable actuating plunger extending toward said key,

a key cap on said plunger, said cap and said plunger having gripping means formed thereon which are constructed so as to allow said cap to be forced on said cap from an initial position, at which said plunger extends into said cap by a minimum amount when said key is at its first orientation, to a final position, at which said plunger extends into said cap by an additional amount corresponding to the actuation of said key to said second orientation so that said cap and said plunger thereafter retain their relative positions upon release of said key to said first orientation.

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