June 25, 1963 H. LE CAINE 3,095,466
KEYBOARD FOR A MONOPHONIC INSTRUMENT WITH
IMPROVED SOUND-SUSTAINING MEANS
Filed Jan. 8, 1959 2 Sheets-Sheet 1

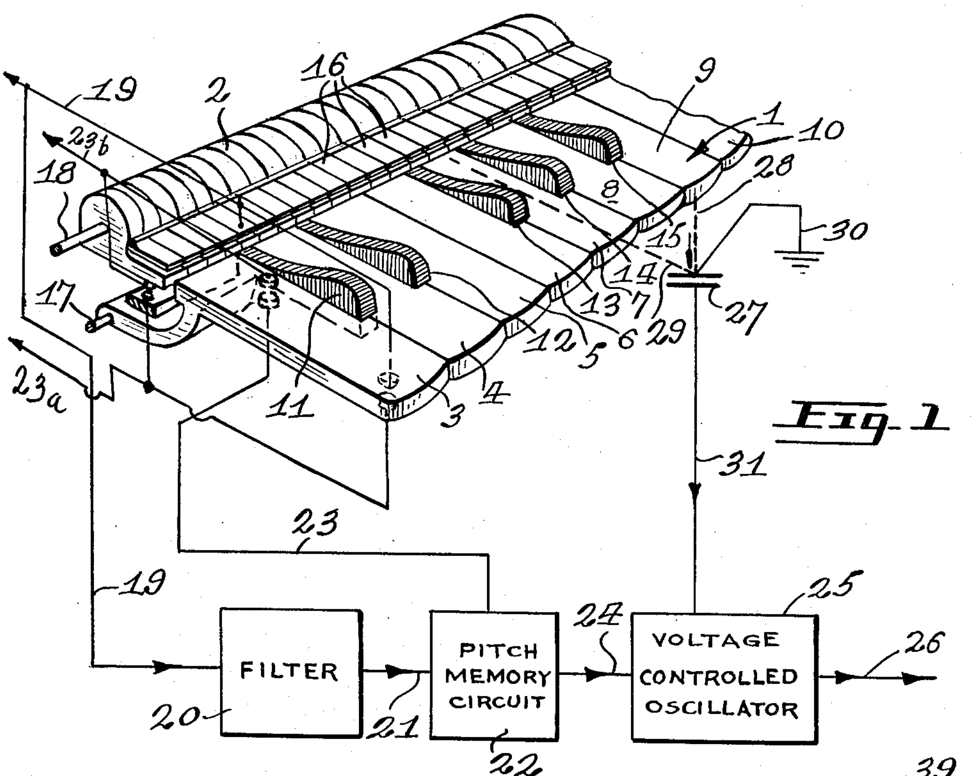

Fig. 1

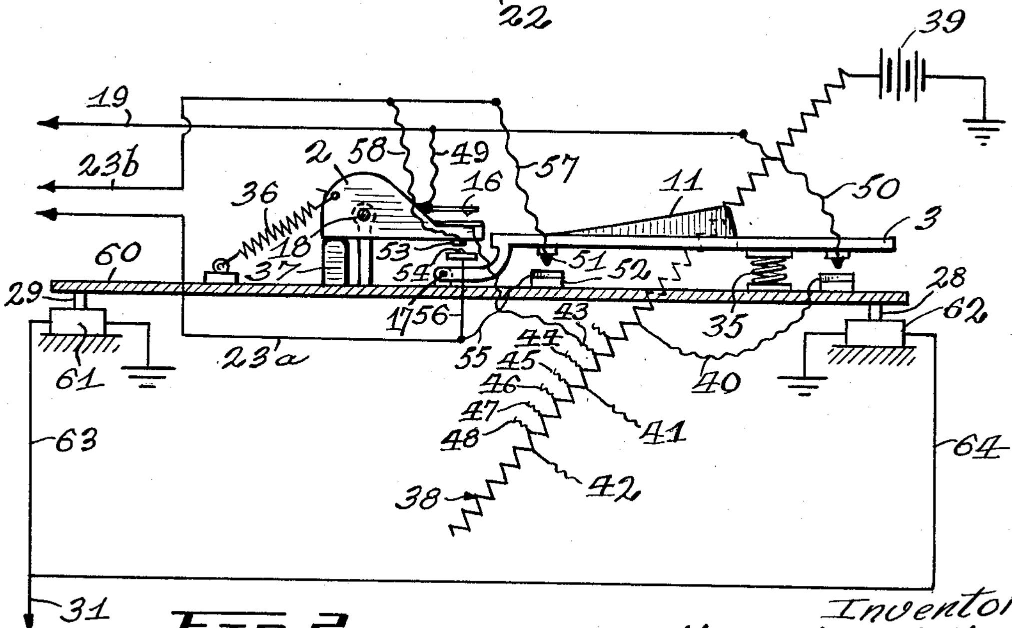

Fig. 2

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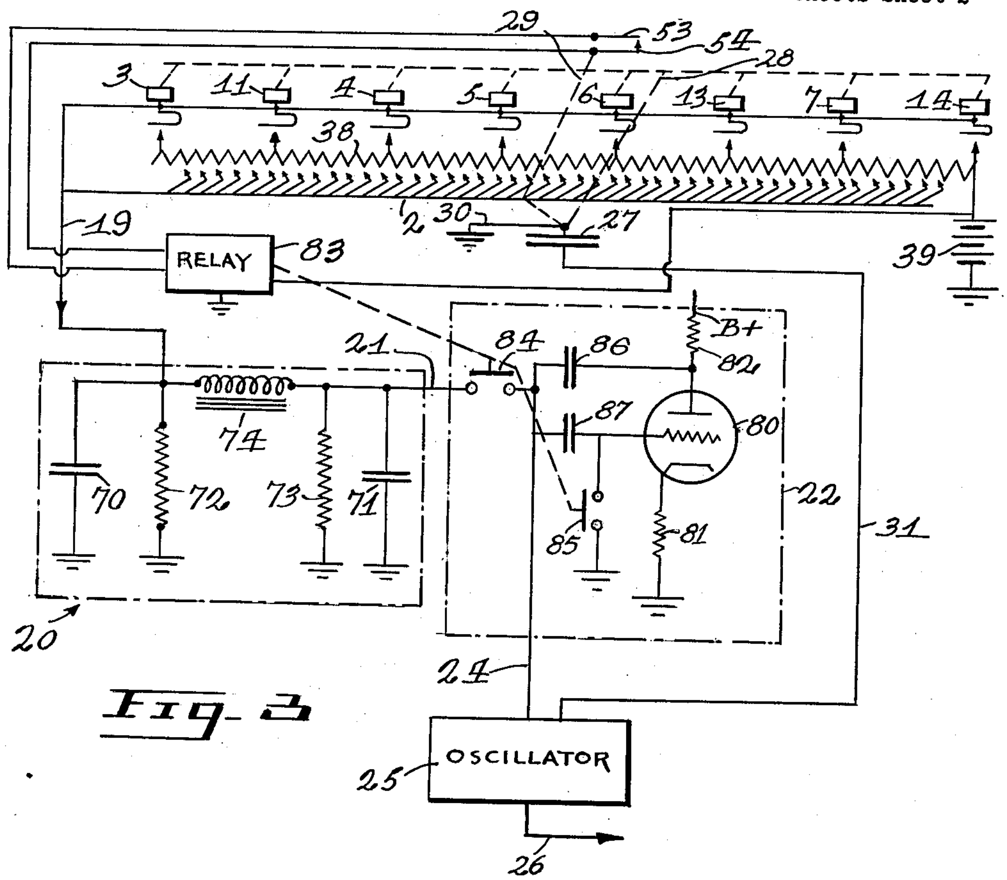

Fig. 3

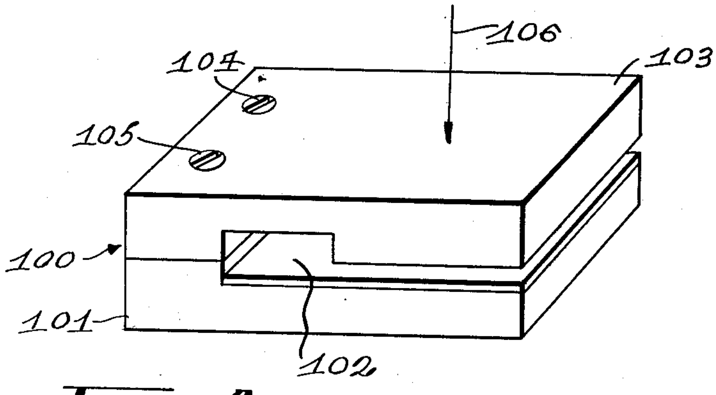

Fig. 4

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KEYBOARD FOR A MONOPHONIC INSTRUMENT WITH IMPROVED SOUND-SUSTAINING MEANS

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This invention relates to musical instruments of the kind having a keyboard of the piano type, and is particularly concerned with such an instrument which is monophonic and capable of performance in relation to special effects such as portamento, off-pitch notes, vibrato and glissando.

The effects achieved by the present invention may be likened roughly to a one-string instrument having both keys for stopping the string at chromatic intervals and provision for keyless or violin-type effects as well.

The present invention makes use of two keyboards. The first is very similar to a piano keyboard and will be denoted herein as the standard keyboard. The second, which may be called the auxiliary keyboard is located immediately behind the standard keyboard.

The standard keyboard controls musical sounds which are fixed intervals apart, for example the ordinary chromatic scale, while the auxiliary keyboard controls notes which are also fixed intervals apart, but considerably closer together than the notes corresponding to keys of the standard keyboard. It is easy to see that by playing adjacent notes on the auxiliary keyboard along with a note on the standard keyboard, and keeping in mind that the whole instrument is monophonic, vibrato and other special effects can easily be arrived at.

Numerous objects and advantages will be apparent from an examination of the present disclosure, the claims and the drawings.

The invention will now be described with reference to the accompanying drawings wherein,

FIGURE 1 is a partly schematic and partly pictorial representation of a preferred embodiment of the invention;

FIGURE 2 shows the key action and the electrical connections associated therewith for the standard and auxiliary keyboard shown in FIGURE 1;

FIGURE 3 illustrates the electrical circuitry of the device shown in FIGURE 1, and,

FIGURE 4 shows an oblique three-quarters view of an example of a touch-sensitive element as recommended for use in connection with the device illustrated in the foregoing figures.

Referring first to FIGURE 1, a standard keyboard is shown generally at **1** and an auxiliary keyboard at **2**. Standard keyboard **1** is recognizable as similar to that used on pianos, organs, and the like and has white keys denoted as **3–10** and black keys denoted as **11–15**. It will be realized that the number of white keys and black keys would ordinarily be considerably greater in number than as illustrated, and would perhaps be similar in extent to a piano keyboard, but the present invention is in no way restricted to the size of the keyboard or the number of keys.

It may well be emphasized at this point that the instrument described herein is monophonic, i.e. only one sound can be heard at one time in the manner of a stringed instrument with one string. Pressing two keys, for example, white key **4** and black key **14** at the same time results in hearing only the higher note, that associated with black key **14**.

The auxiliary keyboard **2** consists of a large number of closely-spaced contact fingers denoted by **16**. Stock of metal having rows of such fingers can be purchased

commercially, usually made of beryllium copper, and known commercially as "finger stock."

It is important to realize that the keys **3–15** of the standard keyboard and the keys **16** of the auxiliary keyboard **2** function in exactly the same manner, only the interval therebetween being different.

As will be discussed below, the keys all function by tapping a resistor at various points so that a particular resistance is associated with a particular note in a voltage-controlled oscillator. The keys **3–15** of the standard keyboard **1** tap the resistor at relatively wide intervals whereas the keys **16** tap the same resistor at considerably narrower intervals, and indeed such that the tones associated with the latter are almost indistinguishable in pitch to the human ear.

The keys **3–15** of the standard keyboard are pivotted about an axis denoted by **17** and the whole auxiliary keyboard **2** rotates slightly about an axis denoted by **18** in a manner to be described below.

A line denoted by **19** conveys the voltages corresponding to various notes to a filter denoted by **20**. The function of filter **20** is merely to smooth out quick changes of pitch as where two keys are played in rapid succession. The "sluggish" action introduced by filter **20** is not such as to introduce an undesirable effect, but merely brings the device more closely to the performance of non-electrical musical instruments such as trombones where there is a transitional period of at least a number of milliseconds between successive notes.

A line denoted by **21** conveys the output of filter **20** to a pitch memory circuit denoted by **22**, and a line **23** also connects from the keyboard section of the device. Pitch memory circuit **22** is a device for causing the notes to "sustain" when the finger is removed from a key. Pitch memory circuit **22** will be described in greater detail below, and for the moment may be said to consist of a device which remembers the last note played and delivers an output which is quite similar to that delivered while the last note was being played, for a reasonably long interval.

The output from pitch memory circuit **22** is taken on a line denoted by **24** to a voltage-controlled oscillator denoted by **25**. Voltage-controlled oscillator **25** is of a kind which is well known and need not be further described. The output of voltage-controlled oscillator **25** is on a line denoted by **26**, which may connect with a loudspeaker, or to additional amplification stages (not shown).

The device illustrated in FIGURE 1 is touch-sensitive, that is, when the keys **3–15** or **16** are pressed, the volume of the resulting notes depends on the force exerted on the keys. This is done by having the device of FIGURE 1 mounted on a series of force-sensitive capacitors, the capacitance of which is increased by increased force. Such a capacitor is shown in FIGURE 4 and will be more fully described in that connection, but in FIGURE 1 a single capacitor of this type is illustrated at **27**. The lines **28** and **29** indicate mechanical linkages whereby force from the keys of keyboards **1** and **2** is conveyed to capacitor **27**. This also indicates that the force-sensitivity is not restricted to a particular keyboard, but force on either results in an increase in volume of sound produced by oscillator **25**.

One side of capacitor **27** is grounded at **30** and the other is connected to oscillator **25** by a line denoted by **31**. The provision for increased volume with force on the keys need not, of course, be related to oscillator **25**, and could be related to a later stage following oscillator **25**, but the form shown in FIGURE 1 will serve to disclose the idea.

Some further details of the invention will now be set forth with reference to FIGURE 2. In FIGURE 2, only one key of the standard keyboard, which is **3** is shown, with part of black key 11 in the rear. Key 3 is pivoted at 17 and is provided with return spring 35. The auxiliary keyboard 2 is pivoted at 18, and the keys 16 are attached to auxilary keyboard 2 as shown in FIGURE 1.

Auxiliary keyboard 2 is loaded with a spring denoted by 36 so that keys 16 tend to move upwardly when not pressed upon by the fingers of the player, and a stop, denoted by 37 limits such motion in a counter-clockwise direction as seen in FIGURE 2.

As already indicated, the keys 3–15 and 16 all function to tap a resistor at various points, thus conveying to filter 20 a voltage which varies according to the key pressed. The resistor is shown at 38. At one end of resistor 38, connection is made to ground through a battery or other source of voltage, denoted by 39. There are various taps denoted by 40, 41 and 42 for connecting to the contacts of keys of the standard keyboard, such as 3, 4 and 5.

There are also a number of taps denoted by 41–48 for connecting to contacts of keys 16 of the auxiliary keyboard 2. The electrical connections for only one such tap is shown, tap 43 which is connected to one of keys 16. The opposite side of the contact at key 16 is connected by a lead denoted by 49 to line 19, and a similar connection is made from the contact of key 3 by a lead denoted by 50 to line 19.

It will be seen that the basis of the sound output is a voltage-controlled oscillator 25, fed with a voltage which varies according to the note desired to be played. The variable voltage is obtained by tapping a resistor 38, connected to a source of voltage, and the taps are spaced at relatively wide intervals for the main chromatic notes in acocrdance with keys 3–15 of keyboard 1, and the taps are spaced at relatively close intervals for the intermediate off-pitch tones in accordance with the vastly larger number of keys 16 of auxiliary keyboard 2. The filter 20, the pitch memory circuit 22 and the touch-sensitive element 27 are refinements, but do not radically change the basic functioning of the device as just described.

The electrical connections for the pitch memory circuit can be seen with reference to FIGURE 2. Key 3 has a pair of contacts denoted by 51 and 52, and auxiliary keyboard 2 a similar pair of contacts denoted by 53 and 54. Contacts 52 and 54 are each connected by leads denoted by 55 and 56, respectively to line 23*a*, and contacts 51 and 53 are connected by leads 57 and 58, respectively, to line 23*b*. Lines 23*a* and 23*b* together correspond to line 23 in FIGURE 1, as it will be realized that one of such lines could be ground and only one actual line is necessary. The double lines of FIGURE 2 are rather to disclose the circuitry than to suggest that two actual lines are necessary. In any event, the lines 23*a* and 23*b*, or line 23, as the case may be are connected to pitch memory circuit 22, and the function in the latter apparatus will be described below.

The touch-sensitive features of the device will now be discussed. In FIGURE 1 there has been shown a single capacitor, linked mechanically to both keyboards 1 and 2. A preferred manner of such linkage is shown in FIGURE 2. Both keyboards 1 and 2 are mounted on a frame denoted by 60. At the regions of the four corners of frame 60 are mounted force-sensitive capacitors denoted by 61 and 62, and as implied by the above, there would be at least two additional capacitors of the same kind. The hatching on the lower side of capacitors 61 and 62 indicates that each is mechanically mounted on a solid base. Electrically, one side of each capacitor 61 and 62 is grounded and the other side is connected to leads 63 and 64, which join in line 31, connected to voltage-controlled oscillator 25, for example, as shown in FIGURE 1.

It may be helpful to make some brief observations on the kind of motion which results in signals being delivered on lines 19, 23 and 31. With reference to the signal on line 19, only one signal at a time may be transmitted. If more than one of keys 3–16 is pressed at one time, only the tap corresponding to the highest note is effective. This is not only advantageous in avoiding errors, but it makes it possible to shift easily from keyboard 1 to keyboard 2 and vice versa. For example, if the player is pressing various notes on keyboard 1 and desires to have vibrato effects associated therewith, he merely places a finger on keyboard 2 between the notes on keyboard 1 being played, and executes a vibrating action.

Referring now to the signal transmitted on line 23 to the pitch memory circuit, it will be seen that each of the keys on keyboard 1 has associated therewith a pair of contacts like contacts 51 and 52, whereas only the whole keyboard 2 has a contact pair, 53 and 54. In other words, the sustaining signal is produced individually when each of keys 3–15 is pressed, but with regard to keyboard 2, force anywhere on the same rotates the keyboard 2 in a forward direction and closes the contacts 53 and 54.

The force-sensitive feature is brought into play by the pressing of any key on either keyboard because the capacitors 61 and 62 are not connected with any of the individual keys but with the frame 60.

Somewhat more elaboration in the electrical features of the device can be seen with reference to FIGURE 3. Keys 3, 11, 4, 5, 6, 13, 7 and 14 are shown in relation to the contacts tapping resistor 38 connected to battery 39 and line 19. The much closer spacing of the keys on keyboard 2 is also illustrated in FIGURE 3.

The components of the filter 20 are seen in FIGURE 3. There is in filter 20 a network consisting of capacitors denoted by 70 and 71, resistors denoted by 72 and 73 and an inductance denoted by 74. Each of capacitors 70 and 71 and resistors 72 and 73 have one end thereof connected to ground. Line 19 carrying the input to filter 20 connects to the ends of capacitor 70 and resistor 72 which are not grounded, as well as to one end of inductance 74. On the other side of inductance 74 are connected the ungrounded ends of resistor 73 and capacitor 71, whence is the output of filter 20 on line 21.

The components of pitch memory circuit 22 are also seen in FIGURE 3. The central feature is the triode denoted by 80, the cathode of which is connected to ground through a resistor denoted by 81 and the plate of which is connected to a high-voltage supply through a resistor denoted as 82. An important part of pitch memory circuit 22 is the relay denoted by 83, operating contacts 84 and 85. The input to pitch-memory circuit 22 enters through contacts 84, on the opposite side of which is a branch line connecting to the plate of triode through a capacitor denoted by 86 and to the grid of triode 80 through a capacitor denoted by 87. The output line 24 is on the side of capacitor 87 away from triode 80. Between the grid of triode 80 and capacitor 87, connection is made to ground through contacts 85.

The pitch memory circuit 22 "remembers" and preserves the pitch in the form of a voltage. The circuit stores information as to the voltage applied to it and retains this voltage for a time sufficiently long that the pitch remains unchanged during the longest delay required. Although circuit 22 is referred to as a pitch memory circuit, it is to be realized that it is a direct current voltage that is retained in the circuit. This direct current voltage is applied to oscillator 25 which gives an alternating current output having a frequency corresponding to the voltage input.

Retention of the voltage for a sufficient time to sustain the tone is achieved by coupling the output voltage on line 21 to the oscillator input line 24 through the electrode-to-ground capacitance of triode 80. A relay-closed switch can be used to short-circuit the electrode-to-ground capacitance of the triode when one of the keys of the instrument is pressed to avoid delaying the start of the corresponding musical tone, the switch being opened to restore the capacitance and sustain the tone when the key is released.

The release of any of the keys causes the opening of a contact such as at 51, 52 and 53, 54, and the opening of all such contacts, by means of relay 83, causes contacts 84 and 85 to be opened. When contact 85 is opened, the effective capacity between the line 24 and ground becomes

$$C_{i-o}=C_1 G_a$$

where C_{i-o} is the said capacity between the line 24 and ground, C_1 is the initial capacity therebetween with the contact 85 open and G_a is the gain of the amplifier stage in pitch memory circuit 22. The above is of course merely an adaptation of the well-known "Miller Effect."

With contact 85 open, the voltage drifts very slowly at a rate dependent on the input impedance of the oscillator 25. The oscillator 25 would normally have a high input impedance, and if so the drift would be slow.

When one of the keys is now closed, as where the player executes a new note, the closing of contact 51, 52 or 53, 54 will cause contact 85 to be closed. This allows the Miller effect to be removed and permits a rapid change in the voltage applied to oscillator 25.

The touch-sensitive action will now be referred to in greater detail. As stated in connection with FIGURES 1 and 2, the touch-sensitive action is produced by capacitor means mounted on the base of the instrument so that force on any key causes force to be applied to one or more of such capacitors, thus increasing the volume of the sound produced.

In FIGURE 4 is shown a preferred embodiment of such a force-sensitive capacitor. The capacitor is shown generally at 100, and the base of capacitor 100 is shown at 101. Base 101 is preferably of insulating material having a conducting coating on the upper right-hand portion of its surface, denoted by 102. A metal plate denoted by 103 is fastened to base 101 by some suitable means such as screws shown at 104 and 105. The arrow shown at 106 indicates the position and direction of the force applied to capacitor 100. The plate 103 is flexed toward the conductive coating 102 in proportion to the force thereon, and thus alters the capacitance of the capacitor 100 in like proportion.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An electronic musical instrument comprising oscillator means for generating a tone at a pitch determined by the voltage of a signal received thereby, a frame, keyboard means on said frame for applying a signal of a selected voltage on said oscillator means and including voltage gradient means and a plurality of key and contact assemblies operable to tap said voltage gradient means at discrete fixed locations, coupling means connecting said keyboard means and said oscillator means, said key and contact assemblies including a first set pivoted on said frame spaced apart a distance to produce chromatic intervals and a second set more closely spaced than said first set and pivoted to said first set, and force sensitive capacitor means connected to said frame for controlling said oscillator means in response to pressure applied on any of said key and contact assemblies, said coupling means including a vacuum triode having an anode connected to a source of electrical power, a cathode connected to ground, and a grid connected to said oscillator means.

2. An electronic musical instrument comprising oscillator means for generating a tone at a pitch determined by the voltage of a signal received thereby, resistance divider means for supplying intermittent signals of related voltages to said oscillator means, a vacuum triode stage having an anode, grid, and cathode, said anode connected through a resistor to a source of high potential, said grid being connected to the input line of said oscillator means through a first capacitor and said cathode being connected through a resistor to ground, a second capacitor connected between the anode of said triode and the input line of said oscillator means, and ganged relay-operated switch means connected in the line between said resistance divider means and the oscillator means and between the grid of said triode and ground such that when the switches are closed the voltage received from the resistance divider means is applied to said oscillator means quickly charging said first capacitor to this voltage level and when the switches are opened the voltage decays slowly due to the large effective capacitance produced by the Miller effect of the triode.

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