Dec. 16, 1941. L. HAMMOND 2,266,030

ELECTRICAL MUSICAL INSTRUMENT

Filed July 5, 1940

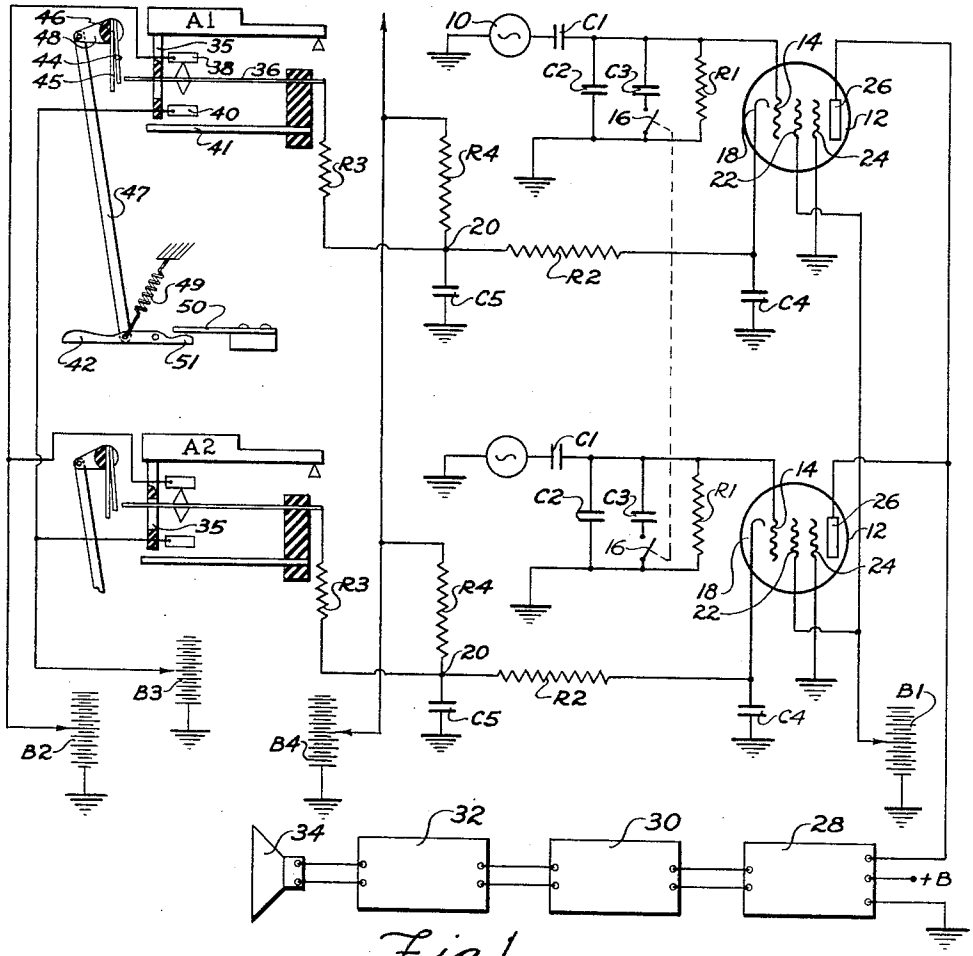


Fig. 1

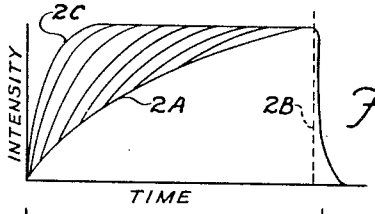


Fig. 2

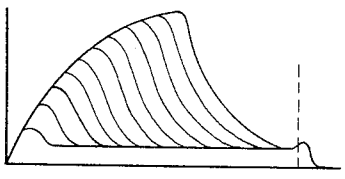


Fig. 4

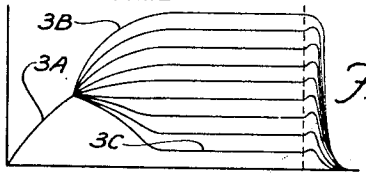


Fig. 3

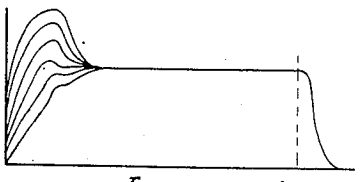


Fig. 5

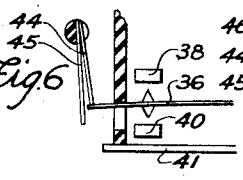


Fig. 6

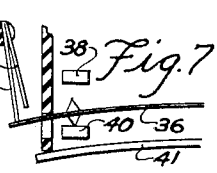


Fig. 7

Inventor
Laurens Hammond
By Benjamin F. Wupper
Atty.

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ELECTRICAL MUSICAL INSTRUMENT

Laurens Hammond, Chicago, Ill.

Application July 5, 1940, Serial No. 343,970

13 Claims. (Cl. 84—1.26)

My invention relates generally to electrical musical instruments and more particularly to key operated control circuits for such instruments, by means of which the intensity envelopes of the tones may be widely varied.

It is an object of my invention to provide an improved electrical musical instrument having a keyboard in which the rate at which the keys are depressed has an effect upon the intensity envelopes of the tones produced.

A further object is to provide improved key operated switching circuits whereby the intensity envelope and the maximum intensity of the tone produced, may be varied in response to the force with which the key is struck.

A further object is to provide an improved sustaining pedal operated control capable of producing a variety of novel musical effects.

Other objects will appear from the following description, reference being had to the accompanying drawing in which:

Figure 1 is a wiring diagram illustrating schematically the essential parts of an electrical musical instrument incorporating the improved key circuits;

Figures 2, 3, 4 and 5 are graphs illustrating representative tone intensity envelopes which may be produced by the improved keying circuits; and

Figures 6 and 7 are fragmentary sectional views showing the key operated switch and sustaining pedal operated control in various operating positions.

The invention may be utilized in making different types of electrical musical instruments such as that for example disclosed in my Patents Nos. 2,126,464 and 2,126,682, the invention constituting a modification of the keying circuits disclosed in said patents. The invention may also be utilized in connection with any other type of electrical musical instrument wherein the intensity envelopes of the tones are controlled by the direct current potentials of terminals, associated respectively with the tone signal generators.

Referring to Figure 1, only two keys, A1 and A2, and their associated key circuits are illustrated. These keys and circuits are intended to be representative of all of the keys of the manual and pedal clavier of an electrical musical instrument. The key circuits are shown as controlling the transmission of frequencies from alternating current sources 10, which may be generators of any suitable type capable of supplying a musical frequency tone signal, preferably of a complex nature. A control tube 12 is provided for each of the generators, the signal from the generator being impressed upon the control grid 14 of the tube 12 through a condenser C1. The grid 14 is normally connected to ground by a condenser C2 and a grid resistor R1.

A condenser C3 is arranged to be connected in parallel with the condenser C2 by operation of a mute switch 16. The switches 16 are preferably gang switches so that all of the switches or groups of them may be closed simultaneously. Closure of the switch 16 tends to reduce the amplitude of the higher frequencies which are present in the signal derived from the generator or source 10, and has an effect similar to that of muting a conventional musical instrument.

The cathode 18 of the tube 12 is connected to ground through a condenser C4 and is connected to a terminal 20 through a relatively high resistance R2, which may be in the order of 4 megohms. The screen grids 22 of the control tubes 12 are connected to a source B1 of adjustable direct current potential, while the suppressor grids 24 may be connected directly to ground. The plates 26 are connected in parallel to adjustable resonant output circuits 28 by which the tone quality may be selectively varied. The signal, modified by the adjustable resonant circuits, is supplied to an expression control device 30 of any suitable construction, and after being amplified by amplifier 32, is translated into sound by a speaker 34.

It will be understood that in this type of instrument, the sources 10 are connected to impress signals upon the grids 14 of the control tubes continuously during the use of the instrument, but that normally no signal is transmitted to the output circuit.

The bias upon the control tubes 12 is determined by the potential of their terminals 20 in a manner more fully described in my aforesaid Patent No. 2,126,464. The present invention is concerned with a novel form of key controlled circuit for determining the potential upon the terminal 20.

Each of these keys A1 and A2 has an insulating actuator 35 capable of operating a single-pole double-throw switch comprising a resilient arm 36 which, when the key is in its normal upper position, makes contact with a bus 38, and which when fully depressed, makes contact with a bus 40. After the key has moved through approximately one half of its stroke, its actuator 35 engages a relatively stiff leaf spring 41.

The switch arm 36 is connected to the terminal

120 through a resistor R3 of relatively low value. The bus bars 38 and 40 are connected to adjustable sources of direct current potential B2 and B3 respectively.

The potential source B2 is adjusted to such positive potential that the tubes 12 are biased just beyond cutoff, and thus are inoperative to transmit a signal.

The potential of the source B3 may be readily adjustable by the player and determines the final sustained amplitude of the tone, since it will be noted that the bias upon the tubes 12 is determined mainly by the source B3 during the time that the keys are held depressed. The terminals 20 are connected to a source B4 of adjustable direct current potential through resistors R4 which are of a value much higher than the resistors R3. Condensers C5 are connected between the terminals 20 and ground, and serve as a means to prevent sudden changes in the potential of the terminal 20.

The sustaining pedal 42 is provided for the operation of sustaining latches 44, 45 individual to each of the switch arms 36, these latches being secured to, but insulated from, a shaft 46. The shaft 46 is operated by the sustaining pedal 42 through a link 47, the ends of which are pivotally connected respectively to the sustaining pedal 42 and to an arm 48 secured to the shaft 46. The sustaining pedal is resiliently returned to normal position by suitable means illustrated as a tension spring 49.

A relatively strong leaf spring 50 is adapted to be engaged by a rearward extension 51 of the sustaining pedal when the latter has been moved to a position in which the latches 44 lie in the paths of movement of their respective switch arms 36, as shown in Fig. 6. Further depression of the sustaining pedal is resisted not only by the spring 49, but by the spring 50, so that an appreciably increased force is required to depress the sustaining pedal a sufficient distance to cause the shaft 46 to swing to the position in which it is shown in Fig. 7, in which position the latches 45 lie in the paths of movement of the ends of their respective switch arms 36.

The latches 44, 45 are preferably in the form of relatively thin leaf springs which, irrespective of their positions, do not appreciably interfere with the downward flexing of the switch arms 36, but are effective, when in the position shown in Fig. 6 to hold the switch arms in an intermediate position upon release of the key, and, when in the position shown in Fig. 7, to hold the switch arms in their lowermost position where they make contact with the bus bar 40.

By virtue of the springs 41 which are engaged by the ends of the actuators 35 when the switch arms 36 are in their intermediate positions, the player can readily control his touch so that the switch arms 36 may be flexed to an intermediate position in which they make contact with neither of the bus bars 38 to 40, or may be fully flexed to make contact with the bus bar 40. Similarly, the provision of the spring 50 aids the musician in selectively swinging the sustaining latches 44, 45 either to the positions in which these latches are shown in Fig. 6 or to the positions in which they are shown in Fig. 7.

Thus, assuming that the sustaining pedal is depressed to its intermediate position so as to bring the latches 44, 45 to the positions in which they are shown in Fig. 6, the switch arms 36 of any keys which are depressed will be prevented from returning to normal position, being arrested by their latches 44. Likewise, any keys which are being held in depressed positions when the sustaining pedal is thus operated, will have their switch arms 36 arrested in the intermediate positions when the keys are released.

In a similar manner, when the sustaining pedal is fully depressed so as to swing the latches 44, 45 to the positions in which they are shown in Fig. 7, any keys which are fully depressed will have their switch arms held in lowermost position, making contact with the bus bar 40 as long as the sustaining pedal is maintained in its fully depressed position. Also, the switch arms 36 of such keys as are depressed at approximately one half of their stroke will be held in such partially depressed position by their associated latches 44. Similarly, the switch arms associated with such keys as happen to have been fully or partially depressed at the time that the sustaining pedal is operated through its maximum stroke, will be held respectively in fully depressed or partially depressed position by the latches 45, 44. By virtue of this construction, interesting and unique musical effects may readily be obtained.

Assuming that the sources B3 and B4 are adjusted to the same potential, for example—150 volts, the tone intensity envelopes which may be produced will vary in the rate of attack depending upon the time interval between the breaking of the contact between the switch arm 36 and bus 38, and in making of the contact between said switch arm and the bus 40. Immediately upon breaking the contact with the bus 38, the potential upon the terminal 20 will begin to drop at a rate determined by the values of the resistor R4 and the condenser C5.

As the potential of the cathode 18 is thus made more negative with respect to the grid 14, cathode-plate current will commence flowing through the tube 12 under the control of the signal on its grid 14, thereby producing a signal which is transmitted to the speaker 34. The character of the attack of the tone thus produced is diagrammatically illustrated in Figure 2 by the curve 2A.

It will be noted that the intensity of the note will thus increase at a logarithmic rate as the potential of the terminal 20 approaches that determined by the adjustment of the potential source B4. When, at the completion of the downstroke of the key, the arm 36 makes contact with bus 40, the potential of source B3 is impressed upon terminal 20 through resistor R3. Because of the fact that R3 is of substantially lower value than R4, the potential of terminal 20 will drop at an increased rate as soon as the last-mentioned circuit is completed, with the result that the intensity of the tone will increase at a more rapid rate.

When the key is released and the switch arm 36 again makes contact with the bus 38, the potential of the terminal 20 will rise rapidly to the potential of source B2, which will bias the tube 12 beyond cutoff, and the resultant decrease in the intensity of the tone is represented by the portion of the curve 2A beyond the dotted line 2B, which indicates the time at which the key is released.

In Figure 2, the curve 2C represents the intensity envelope of the tone when the key is very rapidly depressed and the potentials of the sources B3 and B4 are approximately equal. The family of curves intermediate the curves 2C and 2A illustrate the envelopes of tones produced

when the key is depressed with intermediate velocities. Thus, Figure 2 illustrates some of the tone intensity envelope variations which can be obtained merely by variation in the velocity of the key stroke.

The curves of Figure 3 illustrate the results of variations in the potential of the source B3. The common portion 3A of the curves represents the gradual increase in intensity during the interval between the breaking of the connection with the bus 38 and the making of the connection with the bus 40. The uppermost curve 3B illustrates the condition when the potential of the bus 40 is greatly negative with respect to ground, while the curve 3C illustrates the condition when the source B3 is adjusted to a much less negative potential. The curves intermediate the curves 3B and 3C illustrate the portion of the tone intensity envelope which will result from adjustment of the source B3 to potentials intermediate those which result in the tone envelopes of curves 3B and 3C.

Figure 4 illustrates a series or family of curves showing the intensity envelopes of the tones produced when the potential of B4 is maintained constant at a relatively large negative value, with the potential of source B3 adjusted to a small negative value, and the key depressed at different velocities.

Figure 5 illustrates a family of curves showing the intensity envelopes of tones which may be produced, assuming that the key is operated at the same velocity and assuming that the potential of the source B3 is maintained at an intermediate negative value, while the potential of B4 is successively adjusted to increasing negative potential.

The intensity envelope curves of Figs. 2 to 5 inclusive are merely representative of a large number of different forms the envelopes may take, depending upon the adjustment of the potential sources B3 and B4, and upon the velocity of the key stroke. It will be apparent that by proper adjustment of the potentials of B3 and B4, and by striking the key with different velocities, the player may readily produce tones of a wide variety of different intensity envelopes simulating the acoustic envelopes of the tones of plucked strings, a piano, or a wind instrument.

When the key is in its normal position, the terminal 20 is of course connected to the terminal B4 through the high resistance R4, but due to the fact that this resistance may be in the order of ten times as great as the resistance of R3, the potential of the terminal 20 will be of a value much closer to that of the source B2 than that of the source B4. As an illustrative example, the resistance R4 may have a value of approximately 500,000 ohms when the resistance R3 has a value in the order of 50,000 ohms. It will be noted that the resistances R3 and R4 are of much lower order of value than the resistance R2 which may have a value of approximately 4 megohms.

The condenser C5 should have a value sufficiently great with respect to the value of R4 that even when the potential of source B4 is adjusted to a very high negative value, the rate of change of the potential of terminal 20 will not be excessively great, upon the initial portion of the downward stroke of the key, but will nevertheless be sufficiently rapid to produce a sharply percussive tone. The condenser C5 may have a value in the order of .3 mfd., or a greater value, depending upon the values chosen for the resistances R3 and R4 and upon the degree of percussiveness of tonal attack which is desired.

When the sustaining pedal 42 is partially depressed so that the latches 44, 45 are in the positions in which they are shown in Fig. 6, the tones controlled by such of the keys as happen to be depressed at the time will continue to sound after the release of the keys, at an intensity determined by the adjustment of the potential source B4. Similarly, if, while the sustaining pedal 42 is held in this intermediate position, a key is depressed, its switch arm 36 will, upon release of the key, be latched in its intermediate position, and the tone thus continue to sound at an intensity determined by the potential of B4.

When the sustaining pedal is fully depressed so as to swing the latches 44, 45 to the positions in which they are shown in Fig. 7, such keys as happen to be fully or partially depressed at the time will have their switch arms 36 held respectively in fully or partially flexed positions, and the notes controlled thereby will thus sound at intensities determined respectively by the adjustment of the potential sources B3 and B4. Likewise, if, while the sustaining pedal is held fully depressed one of the keys is partially depressed, its switch arm 36 will be latched in partially depressed position, and the tone controlled by the switch arm will continue to sound after the release of the key, at an intensity determined by the adjustment of the potential source B4. On the other hand, the switch arms of such keys as are fully depressed will be held by the latches 45 in contact with the bus bar 40 so that upon release of their keys, the notes controlled thereby will continue to sound at an intensity determined by the adjustment of the potential source B3.

The musician thus has at his control, by the use of the sustaining pedal, a means to cause tones to be sustained at different intensity levels, depending upon the adjustment of the sources B3 and B4, and when the sustaining pedal is fully depressed, the intensity at which the tone is sustained may be at either the level determined by the adjustment of source B3 or at an intensity determined by the adjustment of the source B4, depending upon the extent to which the key is depressed. The musician may therefore obtain a large variety of different musical effects by proper control of the sustaining pedal, and by the extent of depression of the keys.

From the foregoing, it will appear that I have provided a very simple and effective key circuit for electrical musical instruments, whereby the shape of the intensity envelopes of the tones may be controlled by the touch of the player, and in which other adjustments may be made to provide for additional variations in the tone intensity envelopes. Thus, while I have shown and described but a single embodiment of my invention, it will be apparent to those skilled in the art that numerous variations and modifications of the circuits may be made without departing from the underlying principles thereof. I therefore desire to include within the scope of the invention as defined by the following claims, all such variations and modifications by which substantially results of the invention may be obtained by substantially the same or equivalent means.

I claim:

1. In an electrical musical instrument for producing musical tones of predetermined intensity envelopes and in which there is for each note to be sounded a terminal, the direct current potential of which determines the intensity of the note, the combination of a key operated switch arm, a pair of contacts engageable by said switch

arm, said arm engaging the first of said contacts when the key is in normal raised position and engaging the second of said contacts when the key is in fully depressed position, adjustable sources of direct current potentials connected respectively to said contacts, an additional adjustable source of direct current potential, a high resistance connecting said additional source to said terminal, and a relatively low value resistance connecting said switch arm to said terminal.

2. In an electrical musical instrument in which there is a terminal for each note to be sounded and in which the direct current potential impressed on said terminal determines the intensity at which the note is sounded, the combination of a key operated switch normally connecting said terminal through a low value resistance element to a point having a potential of insufficient value to cause the sounding of the note, a source of direct current potential of adjustable value, and a resistance of relatively high value permanently connecting said source with said terminal.

3. In an electrical musical instrument having a plurality of generators of electrical impulses of musical frequencies, an output circuit including electroacoustic translating means, keys for controlling the transmission of impulses from said generators to said output circuit, and in which there is a terminal associated with each key and generator controlled thereby, the potential of the terminal determining the amplitude of the impulses transmitted from the generator to the output circuit, the combination of a switch arm operable by depression of one of the keys, a relatively low value resistance element permanently connecting said arm with its associated terminal, a resistor of relatively high value having one end permanently connected to said terminal, an adjustable direct current potential source connected to the other end of said resistor, said source being adjustable to a value to cause high amplitude impulses to be transmitted to said output circuits.

4. In an electrical musical instrument having a terminal the direct current potential of which determines the amplitude at which a tone is sounded, means for controlling the direct current potential of said terminal comprising, a depressible key, a break switch opened by said key during the initial portion of the downward stroke thereof, a make switch closed by said key near the end of the downward stroke thereof, a first source of direct current potential of value less than that required on said terminal to cause a tone to sound, a relatively low value resistor connected between said terminal and one pole of each of said switches, means connecting said first source to the other pole of said break switch, an adjustable second source of direct current potential connected to the other pole of said make switch, an adjustable third source of direct current potential, a resistor of relatively high value connecting said third source to said terminal, and a condenser connected between said terminal and a point of fixed potential.

5. In an electrical musical instrument in which there is a terminal for each note to be sounded and in which the direct current potential impressed on said terminal determines the intensity at which the note is sounded, the combination of a low value resistance element, a key operated switch mechanism normally connecting said terminal through said low resistance element to a point having a potential of insufficient value to cause the sounding of the note, a source of direct current potential of adjustable value, a resistance of relatively high value permanently connecting said source with said terminal, a second source of direct current potential, and means for connecting said second source to said terminal through said low value resistance element upon completion of the downstroke of the key.

6. In an electrical musical instrument having a terminal the direct current potential of which determines the amplitude at which a tone is sounded, means for controlling the direct current potential of said terminal comprising, a depressible key, a break switch opened by said key during the initial portion of the downward stroke thereof, a make switch closed by said key near the end of the downward stroke thereof, said switches including a contact arm moved by said key and forming a pole common to both of said switches, a first source of direct current potential of value less than that required on said terminal to cause a tone to sound, a relatively low value impedance connected between said terminal and said contact arm, means connecting said first source to the other pole of said break switch, an adjustable second source of direct current potential connected to the other pole of said make switch, an adjustable third source of direct current potential, an impedance of relatively high value connecting said third source to said terminal, and a condenser connected between said terminal and a point of fixed potential.

7. In an electrical musical instrument, a key, a switch member movable by said key from its normal position to one of a plurality of operative positions, a sustaining pedal, and latching means operated by said sustaining pedal to hold said member in the particular operative position to which it was moved by said key.

8. In an electrical musical instrument, the combination of a key, a switch member movable by said key from normal position to either one of two operative positions, a sustaining pedal, and latching means operated by said sustaining pedal to hold said member in a particular one of said operative positions upon release of the key irrespective of the operative position to which said member was moved by said key.

9. In an electrical musical instrument, the combination of a key, a switch member movable by said key from normal position to either one of two operative positions, a sustaining pedal, means movable by said sustaining pedal from normal position to one of two operative positions, said means being effective when in one of its operative positions to hold said switch member in one only of its operative positions, and said means being effective when in the other of its operative positions to hold said switch member in either of the operative positions to which it may be moved.

10. In an electrical musical instrument having a plurality of keys, switch means controlled by said keys to cause tones to sound, the intensity of the tones being determined by the extent of depression of the keys, and sustaining means cooperative with said switch means to sustain the tones at the intensity levels determined by the extent of depression of said keys.

11. In an electrical musical instrument, the combination of a key, a switch member movable by said key from normal position to any one of a plurality of operative positions, a sustaining

pedal, a plurality of latches respectively engageable with said switch member to hold said member in any one of its plurality of operative positions, and means connecting said latches to said sustaining pedal for operation thereby to different positions in which said latches are respectively rendered operative to engage said switch member.

12. In an electrical musical instrument, the combination of a key, a switch member movable by said key from normal position to any one of a plurality of operative positions, a sustaining pedal, a plurality of latches respectively engageable with said switch member to hold said member in any one of its plurality of operative positions, and means connecting said latches to said sustaining pedal for operation thereby to a position in which said latches are rendered operative to engage said switch member, and to hold said switch member in any operative position to which it may be moved.

13. In an electrical musical instrument, the combination of a key, a switch member movable by said key from normal position to any one of a plurality of operative positions, a sustaining pedal, a plurality of latches respectively engageable with said switch member to hold said member in any one of its plurality of operative positions, means connecting said latches to said sustaining pedal for operation thereby to different positions in which one or both of said latches are respectively rendered operative to engage said switch member, and resilient means to impede movement of said sustaining pedal to the position in which it renders both of said latches operative.

LAURENS HAMMOND.