March 25, 1969 R. B. SCHRECONGOST 3,435,123

ELECTRICAL MUSICAL INSTRUMENT KEYING SYSTEM

Filed May 24, 1965 Sheet 1 of 2

Fig. 2.

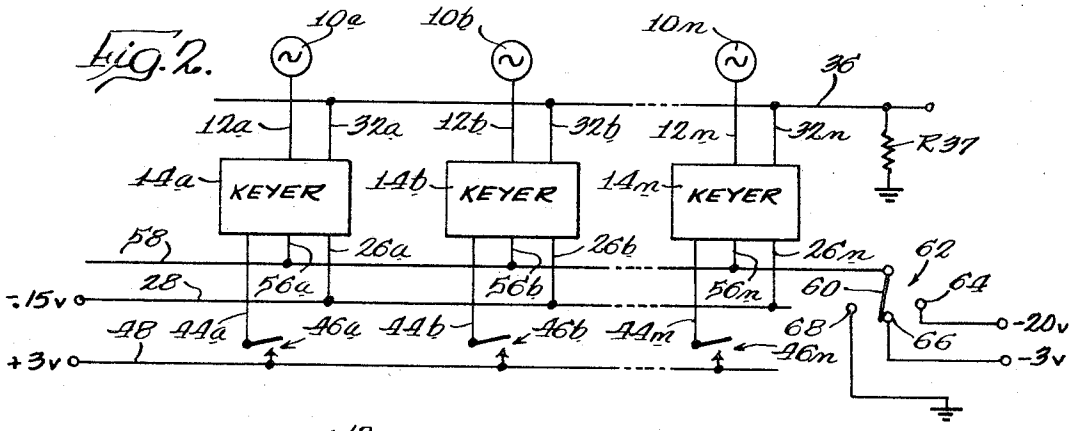


Fig. 1.

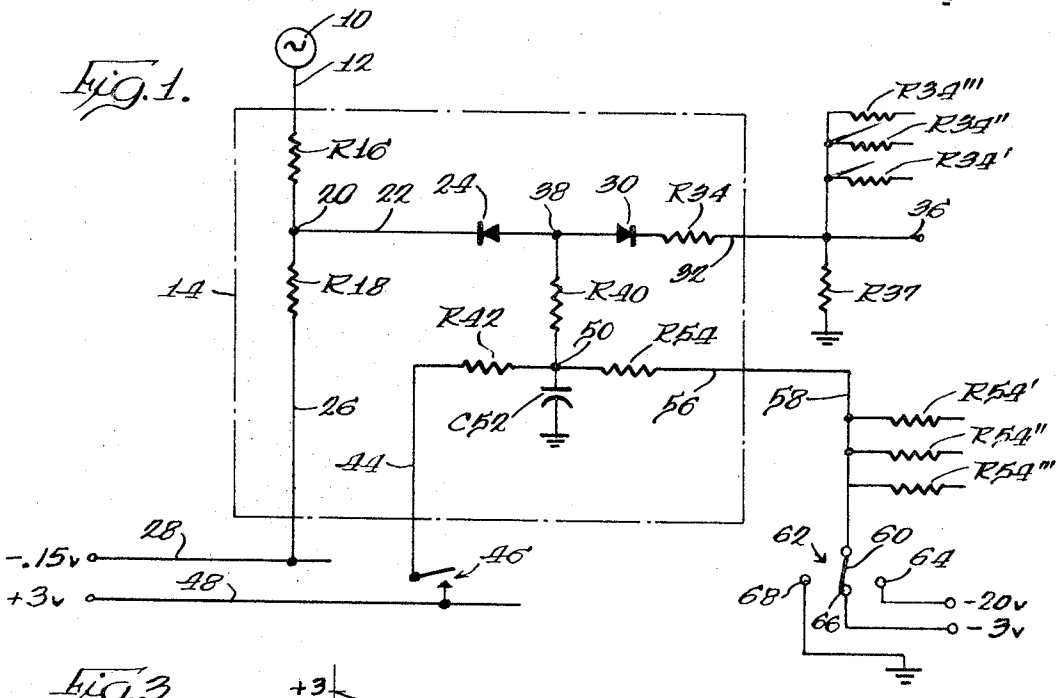


Fig. 3.

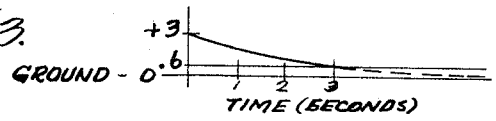


Fig. 4.

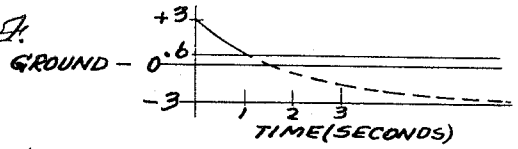
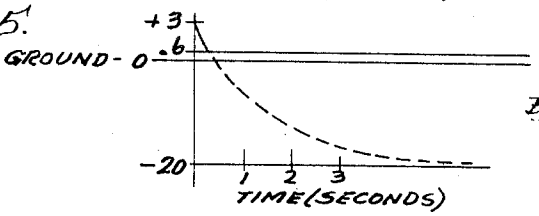


Fig. 5.



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Fig. 6.

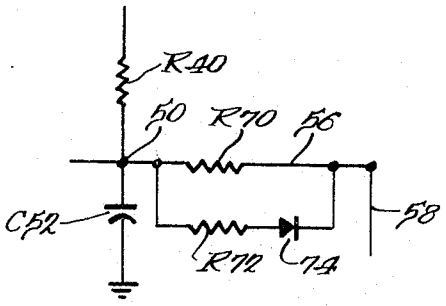


Fig. 7.

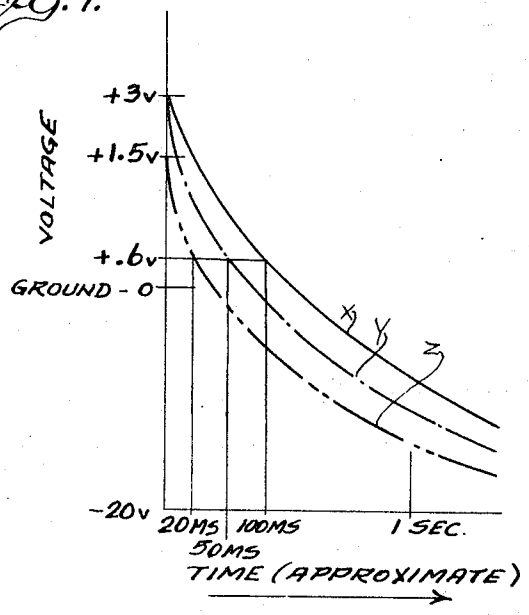


Fig. 8.

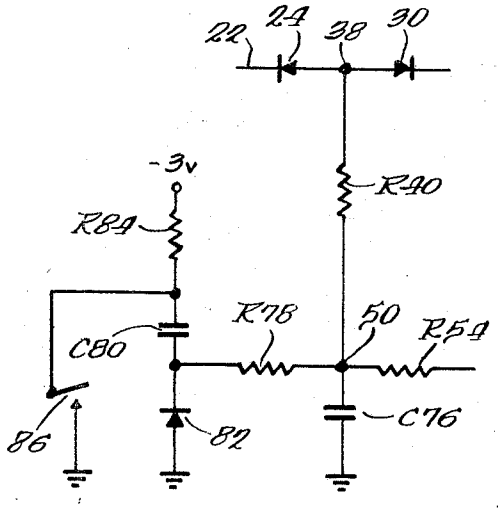
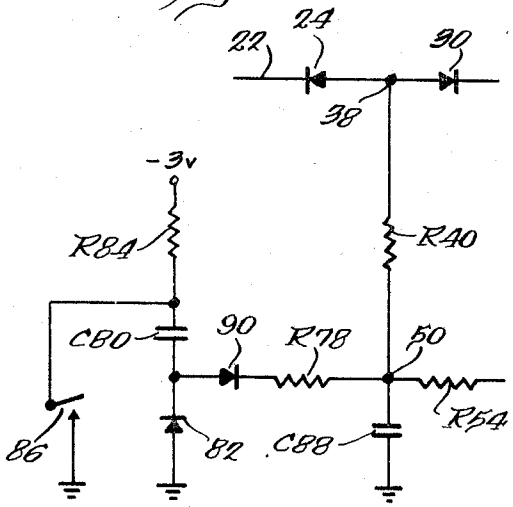


Fig. 9.



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ELECTRICAL MUSICAL INSTRUMENT KEYING SYSTEM

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U.S. Cl. 84—1.26 6 Claims

ABSTRACT OF THE DISCLOSURE

An electrical musical instrument keying system which provides double diode keyers for each signal source to be keyed. All keyers are normally held off by a common bias voltage which is variable, and are turned on individually by a keyed counter voltage which overcomes the bias voltage for the particular keyer. RC timing circuits are used to control decay subsequent to disconnection of the keying voltage source. Decay rate is variable depending upon the selected level of the common bias voltage. Variations in the basic system include provision of a dual slope decay envelope by the addition of a resistor and diode connection in the RC timing circuit and the provision of two types of percussion by the incorporation of RC and diode connections in the keying circuits.

This invention relates generally to electrical musical instruments such as electric organs and similar tone-producing devices, and is more particularly related to apparatus for controlling the decay rates of musical tones produced by such instruments. The invention is concerned more specifically with controlling the operation of keying circuits employed in electric organs or other key-actuated electrical musical instruments whereby the rate of change in amplitude of tone signals may be controlled so that the sounds produced by such signals may be made to decay from their maximum strength at predetermined rates within the control of the player. By means of the invention, therefore, a variety of pleasing and interesting tonal effects may be produced affecting the mood of the music being played and subject to selection by the player.

Although electric organs have previously been made wherein the rate of decay of the notes played was subject to a certain amount of control by the player, so far as I am aware such devices have been limited for the most part to systems requiring a large number of expensive electrical components and complex switches, and thus were not economically suitable for many commercial uses.

It is therefore a broad object of this invention to provide simple and inexpensive apparatus for use with electrical tone-producing instruments which permits control by the player over the rate of decay of notes played by the instrument.

It is a further object of the invention to provide apparatus of the type mentioned in the foregoing object which is capable of selectively providing long and medium sustain and substantially instantaneous stop playing by adjusting one voltage in a system of many keyers used in the instrument.

A further object of the invention is to provide means for controlling the potential at a terminal in a keyer used in an electrical organ system wherein the keyer is connected between a tone signal source and the organ output system, and wherein the keyer is capable of changing the amplitude characteristics of the signal supplied to the output system depending on the potential applied to such terminal in the keyer.

Other objects, advantages, and features of this invention will be apparent from or pointed out in the following specification considered in connection with the accompanying drawings showing a preferred embodiment of the invention. In the drawings, wherein like numerals refer to the same or similar parts in the several figures:

FIG. 1 is a diagrammatic representation of a keying system of a keyer-operated electrical musical instrument, including a preferred form of keyer and showing preferred means in accordance with the present invention for controlling the rate of decay of electrical signals transmitted by the keyer to its output conductor;

FIG. 2 is a more general diagrammatic represenation of a keying system of an electrical musical instrument illustrating the use of a multiplicity of keyers of the type shown in FIG. 1 and the manner in which the decay rates of electrical signals transmitted by such independent keyers are controlled as a group by a single control means in accordance with the present invention;

FIGS. 3, 4, and 5 are diagrams illustrating the rate of change in the decay characteristics of electrical tone signals supplied by a keyer of the type shown in FIG. 1 to its output conductor, under several modes of operation.

FIG. 6 is a diagram of a network adapted to be substituted for a component of the system shown in FIG. 1, for improving the performance of the system;

FIG. 7 is a diagram comparing the decay characteristics illustrated in FIG. 5 with the decay characteristics of electrical tone signals supplied to the output system by a keyer modified by inclusion of the network of FIG. 6, under two modes of operation;

FIGS. 8 and 9 are diagrams showing networks which may be substituted for a component of the system shown in FIG. 1, for providing different modes of operation of the system.

Referring now particularly to FIG. 1, the invention is there diagrammatically illustrated as incorporated in the circuit of an electric organ of the type in common use wherein an individual tone signal source is provided for each of the audio-frequency signals corresponding to the notes within the range of the instrument. Such tone signal sources may be of any suitable type, such as electronic oscillators, with or without associated frequency dividers, for instance. In the embodiment shown in the drawing it will be considered, in the interest of being specific, that the invention is applied to a single manual keyboard having electronic generators as the source of the audio-frequency signals. It will, of course, be understood that the invention is applicable to more than one organ keyboard, including, if desired, a pedal keyboard.

In FIG. 1 there is shown a tone signal source **10**, such as an electronic oscillator, coupled through a lead **12** to a keyer shown enclosed in a box and indicated generally at **14**. The keyer **14** includes a high impedance element or resistor **R16** in series with a resistor **R18** of lower resistance, the common connection **20** of these resistors being connected by a lead **22** to one side of a diode **24**. The remote end of the resistor **R16** is connected to the lead **12**, and the remote end of the resistor **R18** is connected by a lead **26** to a common lead **28** connected to a source of low, preferably negative, potential, for example −0.15 volt. In series with the diode **24** is a second diode **30**, the other side of which in turn is connected through an output conductor **32**, containing a resistor **R34**, to a common lead **36** to the output system of the instrument, the lead **36** being grounded through an impedance element such as a resistor **R37**. The output system of the instrument is not shown since it does not constitute part of the present invention, but it may be of conventional design including electroacoustical translating means for translating into sound the signals supplied to the lead **36**.

Also connected to the common lead **36** are a plurality of other resistors, such as R34', R34'', and R34''' corresponding respectively to the resistor R34 and illustrative of such resistors in all of the other keyers in the organ system. The diodes **24** and **30** are disposed back-to-back and are oriented in the circuit to pass direct current outwardly from a common terminal **38** between them, and each diode becomes conductive to an alternating current signal when the potential on the terminal **38** exceeds the extinction potential of the diode. The diodes **24** and **30** thus constitute a variable impedance signal transmission device which is normally non-conductive, but which becomes conductive when the potential at the terminal **38** exceeds the extinction potential of the diodes. Accordingly, the amplitude characteristics of the tone signal transmitted through the diodes to the instrument output system are dependent upon the potential applied to the terminal **38**. In the embodiment being described, the diodes **24** and **30** have equal extinction potentials of 0.6 volt. Diodes suitable for this purpose are the typical silicon junction diodes of commerce.

The terminal **38** is connected through a resistor R40 of high resistance and a resistor R42 of low resistance, in series, and through a lead **44** to a switch **46** by which the keyer may be connected to a common lead **48** connected to a source of positive potential; for example, +3 volts. The switch **46** is adapted to be operated by a playing key (not shown) of the organ in well known manner; that is, the pressing or actuating of the associated playing key closes the switch **46**, whereby the potential at the terminal **38** is raised above the extinction potential of the diodes **24** and **30**, rendering them conductive, and thus conditioning the keyer to transmit to the organ output system a signal corresponding to that provided by the signal source **10**. Conversely, releasing such playing key opens the switch **46**, causing the potential at the terminal **38** to drop below the extinction potential of the diodes, rendering them non-conductive, whereby passage of such signal to the organ output system is discontinued, as will be more fully described hereinafter.

The junction or common connection **50** to resistors R40 and R42 is connected through a capacitor C52 to a source of bias potential below the extinction potential of the diodes **24** and **30**, such as ground. The junction **50** is also connected through a resistor R54 of high resistance and a lead **56** to a common lead **58** connected to the blade **60** of a step switch **62** having a plurality of terminals, here shown as three, i.e., terminals **64**, **66**, and **68**, connected respectively to sources of different potential each of which potentials is lower than the aforementioned extinction potential, but none of which is higher than that of the said bias potential source connected to the capacitor C52. The sources of potential connected to the said terminals **64**, **66**, and **68**, may be, for example, −20 volts, −3 volts, and ground potential. Also connected to the common lead **58** are a plurality of other resistors, such as R54', R54'', and R54''', corresponding respectively to the resistor R54 and illustrative of such resistors in all of the other keyers in the organ system.

Referring to FIG. 2, there is illustrated diagrammatically an organ keying system employing a plurality of keyers identical to those previously described and shown in FIG. 1, FIG. 2 also showing the manner in which the keyers are incorporated in the main organ circuit. In FIG. 2 the reference numerals for the various parts are the same as those used for similar parts in FIG. 1, with differentiating suffixes *a*, *b*, and *n* to denote groups of assocaited parts, to facilitate the description.

The outputs of the audio-frequency signal generators **10***a*, **10***b*, and **10***n* are coupled respectively through their associated leads **12***a*, **12***b*, and **12***n* to keyers **14***a*, **14***b*, and **14***n* identical to the keyer **14** previously described. Although only three keyers are shown for purposes of illustration in FIG. 2, it is to be understood that the number of such keyers used in the organ system depends upon the number of playing keys in the instrument which have the invention applied thereto.

The keyers **14***a* to **14***n* are also connected respectively through their associated leads **26***a* to **26***n* to the common −.15 v. lead **28**, through their associated leads **44***a* to **44***n* to the playing key switches **46***a* to **46***n*, and through their associated leads **56***a* to **56***n* to the common control lead **58**. The keyers **14***a* to **14***n* are likewise connected through their respective associated output conductors **32***a* to **32***n* to the common lead **36** connected to the instrument output system.

In an organ system in which the amplitude of the signals supplied to the keyers is about 1.5 volts and the potentials supplied to the lines **28**, **48**, and **58** are as indicated above, I have found that good results are obtained when the components of the keyers have the following values, wherein the resistances of the resistors are in ohms (K representing 1000):

Component:	Value
R16	47K
R18	4700
R34, R34', R34''	2200
R37	1000
R40	33K
R42	100
R54, R54', R54'', R54'''	100K
C52 ——microfarads—	20

Operation of the present apparatus will now be described with particular reference to FIG. 1, in which description it will be assumed that the values of the various components and the potentials supplied to the lines **28**, **48**, and **58** are as described above. When the electric organ is turned on, the tone signal sources supply their respective tone signals at constant amplitude to their associated keyers, and therefore the signal supplied by the source **10** is impressed on the lead **22** of the keyer **14**. Assuming the amplitude of the signal supplied to the input lead **12** to the keyer to be about 1.5 volts as mentioned above, the signal potential on the lead **22** will be about 150 millivolts, peak to peak.

Assuming further that the switch arm **60** is in contact with the terminal **68** to ground, if the player now actuates the playing key associated with switch **46**, thereby closing said switch, a potential of about 0.7 to 0.8 volt is impressed on the terminal **38** from the line **48**, capacitor C52 becoming charged at the same time. Since the potential at the terminal **38** thus exceeds the 0.6 volt extinction potential of the diodes **24** and **30**, the diodes become conductive, and the tone signal passes through the diodes to the output conductor **32**, and thence to the output system of the instrument. Transmission of such signal to the output system of the instrument continues at a constant amplitude as long as the switch **46** is closed, i.e., as long as the associated playing key is pressed. Releasing the playing key causes the switch **46** to open, whereupon the capacitor C52 discharges principally through the resistor R54, some discharge also taking place through R34, R37 and R18. The signal continues to pass through the diodes **24** and **30** to the output system on a declining basis until the potential at terminal **38** drops to the extinction potential of the diodes, at which time the diodes become non-conductive and transmission of the signal to the output system ceases. The amplitude of such output signal is therefore progressively reduced, and the sound produced therefrom by the output system correspondingly decays as the capacitor C52 discharges. Because of the negative bias imposed on the lead **22** by its connection through lead **26** to the line **28**, diode **24** becomes conductive slightly before diode **30** when switch **46** is closed, and extinguishes slightly after diode **30** when capacitor C52 discharges after switch **46** is opened, this mode of operation providing a better decay envelope of the signal passing to the output conductor **32** than would be

obtained if the diodes **24** and **30** simultaneously became conductive and then simultaneously extinguished. With the common lead **58** connected to the ground terminal **68** of the step switch **62**, the decay from maximum voltage to the extinction potential of the diode **30** takes about three seconds. This is illustrated in FIG. 3, which shows the relation of voltage at the capacitor C**52** to time, following opening of the switch **46**, the potential at the capacitor decaying exponentially and rather gradually from the maximum of about three volts to ground potential.

If, in operation of the keying system, the arm **60** of the switch **62** engages terminal **66** (—3 volts potential), the decay rate is considerably faster than that just described, the decay from maximum potential to the extinction potential of the diode **30** here taking about one second. This is illustrated in FIG. 4. FIG. 5 illustrates the much faster decay rate obtained when the arm **60** is engaged with the terminal **64** (—20 volts potential) of the step switch, the decay period in this instance being about 100 milliseconds. The moment at which transmission of the signals to the output system ceases is the point shown in FIGS. 3, 4, and 5 at which the curve crosses the horizontal line representing the 0.6 volt extinction potential of the diode **30**.

If a more rapid decay rate is desired, but it is desired not to exceed —20 v. as a connection for the lead **56**, on the ground that this might produce an excessive reversing voltage through the switch **62** during the periodic increase and reduction in potential at the terminal **38**, this can be accomplished by applying a lower voltage, e.g., +1.5 v. instead of +3 v., to the bus **48**. This of course reduces the initial signal voltage at the output conductor **32**, requiring the output signal to be amplified to a greater degree than is necessary when the bus **48** carries 3 volts. Such additional amplification is of course easily accomplished by means well known in the art.

An improved decay envelope shape over that achieved through the use of the simple resistor R**54** in the lead **56** may be obtained by substituting a diode-resistor network therefor, one form of which is shown in FIG. 6. Referring to FIG. 6, it will be seen that the network comprises a resistor R**70** connected at one end to the junction **50** and at the other end to the common lead **58**. Bypassing the resistor R**70** is a second resistor R**72** connected in series with a silicon diode **74** oriented to be conductive when the potential is higher at the junction **50**. When this network replaces resistor R**54** having a resistance of 100K, the resistors R**70** and R**72** preferably have resistances of 220K and 100K, respectively.

Reference is now made to FIG. 7 which graphically depicts the rate of potential drop at the junction **38**, and the decay characteristics of the tone signals passing through diode **30** to the output conductor under various conditions during discharge of the capacitor C**52**. As in FIGS. 3 to 5, the moment when transmission of the respective signals to the output system ceases is shown in FIG. 7 by the intersections of the curves with the horizontal line representing the 0.6 volt extinction potential of the diode **30**. In FIG. 7 all of the curves represent the above-mentioned rate of potential drop and the signal decay characteristics produced by having the mode switch blade **60** in contact with terminal **64** connected to the —20 v. potential source. Curve *x* represents the decay characteristics observed when the energizing voltage from the bus **48** is +3 volts and the simple resistor R**54** is present in the lead **56** for discharging the capacitor C**52**, and shows that the potential on the terminal **38** decays to the extinction potential of diode **30** (0.6 volt) in about 100 milliseconds. Curve *y* depicts the decay characteristics of the signal under conditions similar to those for curve *x*, except that the resistor R**54** has been replaced by the resistor-diode network of FIG. 6, and shows that the potential on terminal **38** decays to the extinction potential of diodes **24–30** in about 50 milliseconds, most of this decay occurring rather quickly. Curve *z* depicts the decay characteristics of the signal under conditions similar to those for curve *y*, except that the energizing voltage supplied by bus **48** is +1.5 volts and shows that the potential on terminal **38** decays quickly to the extinction potential of diodes **24–30** in about 20 milliseconds. The decay envelope of the signal improves, it is believed, resulting in a more pleasing musical effect, as the curves drop more vertically initially.

The improved effects obtained by using the resistor-diode network of FIG. 6, as just described, may also be obtained by using a non-linear resistor, such as a silicon carbide resistor in place of resistor R**54**.

In the foregoing description, the invention has been described as used in conjunction with keying providing sustained playing of a note as long as a key-operated switch is closed. It will of course be understood that the invention is also applicable to keying systems providing other modes of operation, such as percussion, or percussion-sustain systems. Modifications of the keyer of FIG. 1, adapting the keyer for such percussion and percussion-sustain operation, are shown respectively in FIGS. 8 and 9 and are representative of other forms of keyers with which the present invention may be used.

In FIG. 8 the terminal **38** between diodes **24** and **30** is connected through the resistor R**40** to the junction **50** which is connected through the resistor R**54** to the mode switch **62**, as described above. In the embodiment here described, however, the junction **50** is connected to ground through a capacitor C**76**, and is also connected through a resistor R**78** to a common connection to a capacitor C**80** and one side of a diode **82**, the other side of the latter being connected to ground. The diode is oriented to be conductive when the common point between C**80** and R**78** is sufficiently below ground. The capacitor C**80** is connected through a resistor R**84** to a —3 volt D.C. terminal of the power supply, and the common connection to capacitor C**80** and resistor R**84** is connected through a key-operated switch **86** to ground. The other components of the keyer, and its connections to the signal source, the output system, the mode switch **62** and the common lead **28**, are all the same as in FIG. 1 previously described. Suitable values for the added components of the embodiment of FIG. 8 are: 1000 ohms for the resistors R**78** and R**84**, .47 microfarad for capacitor C**76**, and 20 microfarads for the capacitor C**80**.

In operation of the embodiment of FIG. 8, upon closing the switch **86** by pressing the playing key associated therewith, the capacitors C**76** and C**80** become positively charged, and the potential at the terminal **38** is raised above the +0.6 volt extinction potential of the diodes **24** and **30**, whereupon the signal supplied by the signal source **10** passes through the diodes **24** and **30** to the output system of the instrument. The capacitors C**76** and C**80**, which have divided the initial charge on C**80**, immediately begin to discharge, lowering the potential of the terminal **38**, and the transmission of the signal to the output system stops when the potential at terminal **38** drops to the extinction potential of the diode **30**, as described above. Note that this effect is due to the initial charge on C**80** which is divided with C**76**. If the key is held long enough, the decay cycle is automatically completed. If the key is released before completion of the decay cycle, the note is extinguished by reestablishment of the —3 v. connection to the capacitor C**80**.

FIG. 9 is substantially the same as FIG. 8, except that in the former the junction **50** is grounded through a capacitor C**88** and a diode **90** is disposed between the resistor R**78** and the common connection to the capacitor C**80** and the diode **82**. Diode **90** is oriented to pass current toward the junction **50**. A suitable value for the capacitor C**88** is 20 microfarads, and the other capacitors and resistors in FIG. 9 have the values given above. Operation of the modification of FIG. 9 is similar to that of the modification of FIG. 8, except that if the key contact

86 is opened before completion of the potential rundown at the junction 38, capacitor C88 continues to be effective, even though capacitor C80 is discharged. The note is not immediately extinguished, therefore, as in FIG. 8, but trails off at a more rapid rate than prior to key release.

In all of the embodiments of FIGS. 1, 8, and 9, it is seen that decay of the signal commences upon the cessation of conduction of charging current to the capacitor or capacitors in the respective keyers. In FIG. 1 such cessation of charging current is brought about by release of the playing key, which causes switch 46 to open, whereas in FIGS. 8 and 9 the cessation of charging current occurs immediately after the key-operated switch 86 is closed.

Operation of the general keying system used in playing notes of all frequencies within the range of the instrument will be apparent from FIG. 2. Since the keyers 14*a* to 14*n* have parallel connections to the leads 28, 36, and 58, and (through switches 46*a* to 46*n*) to the lead 48, any number of notes may be played simultaneously by actuating or pressing the playing keys corresponding thereto, which in turn will close respective associated ones of switches 46*a* to 46*n*, and each note will decay at the rate established by the position (selected by the player) of the arm 60 of the step switch 62 when the playing key associated with such note is released (FIG. 1), or played (FIG. 8), or played and released (FIG. 9), in the manner described above. Thus, the present invention provides simple apparatus whereby the player can select any one of a plurality of decay rates for signals supplied to the output system by all the keyers in the musical instrument simply by manipulating a single switching member, this control feature being one of the important advantages of the invention.

A further advantage of my invention is that it permits the use of operating voltages (i.e., the voltages impressed on the terminal 38) which are high relative to the voltage of the tone signal input at the diode 24, whereby distortion of the wave form of the signal during the decay interval may be maintained below the limit of perceptibility to the ear.

While I have shown and described a particular embodiment of my invention, it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the spirit and scope of the invention. For example, it will be understood that the extinction potentials of the diodes need not be as given, and that they may be higher or lower than the above mentioned value of 0.6 volt, and may even have negative values. Likewise, the values of the various components of the keyers, and values and signs of the potentials supplied to the lines 28, 48, and 58, are not critical and may be varied, if desired. Such values are all a matter of choice, and one skilled in the art will readily understand how variations therein will affect the operating characteristics of the keying system. It will also be apparent that the invention is not limited to use with the specific keyer described herein, but may be used with other kinds of keyers, such as transistor keyers, tube keyers or keyers containing other solid state devices, in which transmission of a signal through the keyer is dependent on the potential at a given point or terminal therein. I therefore desire, by the following claims, to include within the scope of my invention all such modified forms of the apparatus disclosed herein by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

I claim:

1. A keying system for an electrical musical instrument having a plurality of tone signal sources covering a musical range of several octaves, a common output system, and a plurality of keyers individually connecting the sources to the output system, said keyers individually comprising a pair of diodes in series connected between each source and the output system, said diodes being oriented to pass direct current outwardly from a terminal between them, a plurality of DC bias sources all below the extinction potential of said diodes, a bias lead common to all of said keyers, switch means for connecting any selected one of said bias potential sources to said common bias lead to fix the extinction bias thereon, a timing capacitor for each of said keyers connected to said bias lead, each of the capacitor bias connections including an impedance element, a source of keying voltage above the extinction potential of said diodes, an actuating circuit including a playing key operated switch and an impedance element connected for applying the keying voltage to said timing capacitor by way of the last said impedance element in opposition to the selected bias voltage on said capacitor when said playing key switch is operated, a circuit connecting the terminal between said diodes to said timing capacitor, the last said circuit including an impedance element, and the value of the capacitor bias impedance element being high as compared with the value of the keying voltage impedance element.

2. The keying system as called for in claim 1 in which all of the impedance elements are resistors.

3. The keying system as called for in claim 1 in which the capacitor bias impedance element is a resistor in parallel with a series connected resistor and diode.

4. The keying system as called for in claim 1 in which the keying voltage source is a capacitor, means for charging said capacitor and means including said playing key switch providing a connection for transferring a portion of the charge on the last said capacitor to said timing capacitor when said playing key switch is operated.

5. The keying system as called for in claim 4 in which the connection for transferring charge from the voltage source capacitor to the timing capacitor includes means for preventing transfer of charge in the reverse direction.

6. The keying system as called for in claim 5 in which the means for preventing reverse transfer of charge is a diode.

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U.S. Cl. X.R.

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