Oct. 3, 1961 G. PÖTZL 3,002,411

CONTROL ELEMENTS FOR ELECTRONIC MUSICAL INSTRUMENTS

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Fig. 1.

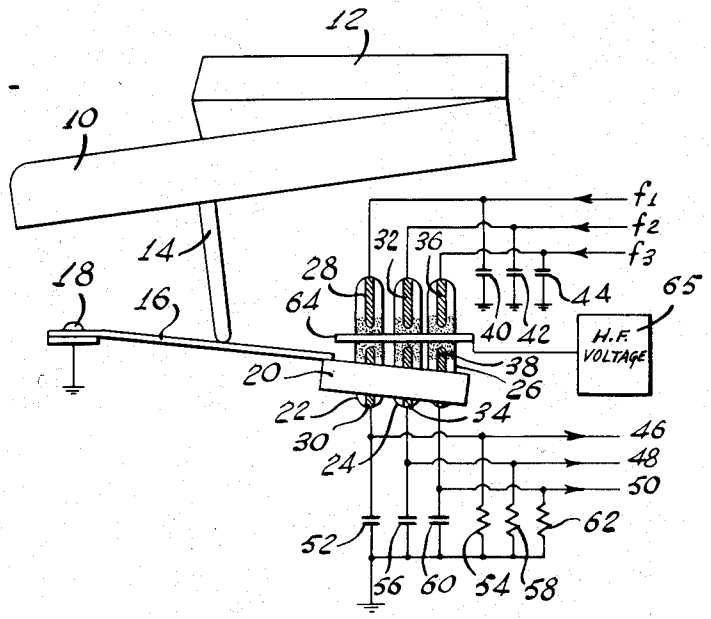


Fig. 2.

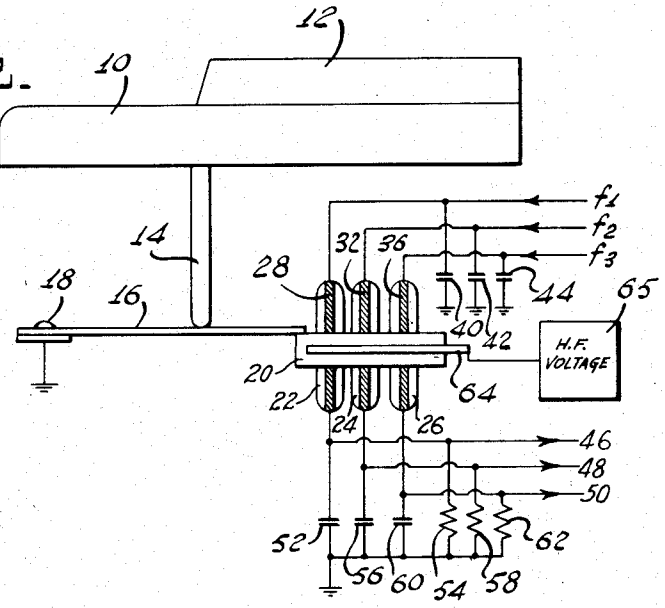
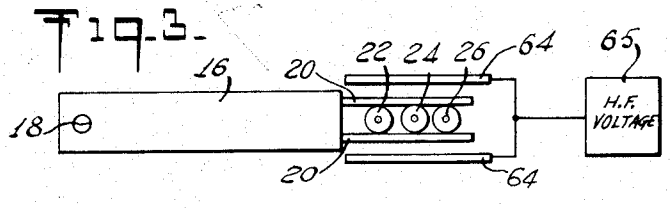


Fig. 3.



INVENTOR
GÜNTER PÖTZL
BY

ATTORNEYS

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CONTROL ELEMENTS FOR ELECTRONIC MUSICAL INSTRUMENTS

Günter Pötzl, Plauen, Germany, assignor to VEB Blechblas- und Signalinstrumentenfabrik Markneukirchen, Markneukirchen, Germany

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This invention relates to electronic musical instruments and in particular to those instruments which require a large number of switches or contact elements in their keyboard systems in order to have one key switch on a corresponding A.C. voltage of sonic frequency.

This invention further relates to instruments where the minimum number of required contact elements is the product of the number of keyboard keys and the number of electrical couplings to the sound source associated with each key. The invention also covers the field of contact elements where numerous requirements exist with respect to ability of operation and absence of switching noise. In addition, by means of this invention it is possible for the contact element to control the sound produced with respect to amplitude and frequency so as to create oscillatory harmonics.

An electronic musical instrument with two keyboards and about sixty keys and with six couplings operating in each key uses a sum total of 720 contact elements or switches. Thus it will be noted that the quality of the contact elements in the key system may be the principal expense of an electronic musical instrument. Because of this, electronic musical instruments almost exclusively use key systems having metallic contacts, which may assume a normally open or a closed position. Metallic switch contacts, however, have disadvantages in a key system of an electronic musical instrument because of the inherent instability and corrosion of metal contact surfaces and because of the static voltage superimposed upon sound frequency voltages, which result in clicks or static. If, for example, in an electronic organ wherein each key actuates several couplings and the individual couplings are arranged so that they are separated from one another and independent and ten keys are simultaneously actuated and six couplings are switched in by each key, then sixty metallic contacts are simultaneously opened and closed and each individual contact produces a static impulse. Because it is physically unlikely that all contacts will be closed and opened at exactly the same time, the sixty contacts create a succession of static pulses producing a strong impression of static noise in all harmonic registers. It is quite possible to dampen this static by so-called "click-filters." However, these simultaneously attenuate the high harmonics of the desired sound frequency voltage because the static noise is preponderantly made up of high frequencies. This means a loss of brilliance of the produced timbres. Besides, it is not possible to control the amplitude and the frequency range caused by the actuated tone frequency voltage and thereby produce harmonic oscillations with a metal switch or relay. The tone content is hard and contains the above explained key clicks.

It is possible to replace a metallic switch contact by a potentiometer whereby lifting of the key varies the resistance and hence controls the amplitude of the sound output, that is the A.C. voltage of sound frequency dependent on the keying. In this way key clicks are also avoided. This method is certainly very expensive and mechanically difficult to produce practically. In addition, despite this, static noises can occur as a result of corrosion of the contact surfaces of the potentiometer which slide upon one another to produce the voltages.

Furthermore, the expenses of the parts would result in a prohibitive price.

Another solution for the problem of contact elements in the key system of an electronical musical instrument is the substitution of semi-conductor elements for the switches. That is, germanium diodes would be used as contact elements. The switch operation of the diodes is accomplished by the polarity reversal of a biasing voltage across the diode and by the thus produced change in internal resistance.

In the unactuated condition the high impedance sound-frequency voltage, introduced to the diode, is reduced by a specific amount, through the then low internal impedance of the diode. In accordance with this principle, the polarity reversal of the diode can occur over time-constant members and reproduction of the oscillatory processes are obtained in a simple manner.

To get the necessary control, and prevent interference between the D.C. voltage biasing circuits from the A.C. sound frequency circuits, and the high impedances necessary in time constant members for the reproduction of the sound sequences which one key may produce, it is necessary to control the polarity reversal of the bias voltage on the diode by means of an electron tube. The time constant members are then appropriately disposed on the control grid and a control grid voltage change produces a plate current change. By particular circuit dimensioning the biasing voltage of the diodes in the anode circuit of the electron tubes are poled reversely in accordance with the time function in the grid circuit time constant members. This method is disadvantageous because of the cost of additional electrical elements. It would be necessary to have an electron tube and a mechanical key for each key on the keyboard for grid bias voltage actuation over the time constant member. The number of necessary diodes would correspond to the number of the otherwise necessary metallic switch contacts. A still further disadvantage of this method is that the sequence of sounds set into the time constant members is rigidly followed once set up. Individual control and influence of the oscillation processes during key actuation of one or more keys is lost as a characteristic condition of the instrumental music.

It is an object of this invention to avoid the disadvantages of key systems presently used in electronic musical instruments.

It is a further object of this invention to provide means wherein the volume of an electronic musical instrument is controlled in the coupling circuit.

It is a further object of the invention to vary the volume of the switch by the keying in a way similar to the operation of an ordinary piano.

In accordance with the invention a gas discharge tube is used as a switch. The function of the switch is accomplished by use of certain properties peculiar to gas discharge tubes. In the un-ionized state the gas discharge path of a gas discharge tube is not conductive. Its internal impedance is comparatively very high. If the gas discharge path of a gas discharge tube is ionized by means of a high frequency A.C. voltage field whose frequency is higher than the appropriate de-ionization time of the ionizable medium and whose voltage is high enough, then the gas discharge path of the discharge vessel becomes ionized and conductive. The internal impedance of the gas discharge path of the gas discharge vessel is principally dependent on the size of the A.C. voltage field across the ionizable medium and the type of ionizable material in the tube.

The electrodes of the gas discharge tube are then connected to provide a path between an existing sonic frequency voltage and an output. The resulting voltage across the gas discharge tube is characterized by a magni-

tude sufficiently under the first and the arc-maintaining voltage of the gas discharge vessel so that the switch may function independently of this voltage across its electrodes and may provide a current path to the network. The sonic frequency voltage to be switched in, therefore, does not cause ionization of the ionizable medium and can not maintain ionization when the high frequency ionizing field which breaks down the ionizable medium is no longer present. The internal impedance of the gas discharge vessel is thus dependent only on the high frequency voltage field which breaks down the ionizing medium and not upon the electrodes of the gas discharge tubes which are used for voltage switching, as long as the latter are at potentials sufficiently under the break-down or arc-maintaining voltage of the ionizable medium of the gas discharge vessel.

In summary the gas discharge vessel is conductive only so long as the ionizable medium is ionized by the application of the A.C. voltage field. By control of the magnitude in the A.C. voltage field, applied to the ionizable medium in the gas discharge tube, by which the gas is ionized and made conductive, the internal impedance presented by the gas discharge tube to the switching voltage across the glow tube electrodes can be controlled. If the gas discharge vessel is used in the switching circuit it can then operate as a controlled variable in a voltage divider to vary the magnitude of the output voltage at the divider point.

By use of these principles for the key system of an electronic musical instrument the gas discharge tube can, for example, simply be a glow tube which in its non-ionized state operates as an open switch for the sound frequency voltage across its electrodes. Should the glow tube be ionized by means of the A.C. voltage field then it becomes conductive and closes the sound circuit. Further, the amplitude of the sound frequency voltage can be regulated by control of the degree of ionization of the tube and thereby its internal impedance, by arrangement as a voltage divider. In instruments where one depression of one key actuates several sounds, it is possible, by controlling the internal impedance of the glow tube, to alter the sequence of initiation of these various sounds.

By controlling the ionization level, glow tubes can act as switch members, or function as a sequence control with respect to its electrodes connected for switching of several existing sound frequency voltages by one key. The control can be extended to regulate the amplitude as well as the sequence of initiation of the various sound frequency voltages which are switched on and off by one key. The control of the ionization level of glow tubes can be made independent of stroke upon the keyboard.

Furthermore, in accordance with the principles of the invention the gas vessel can be used as a switch for D.C. voltages as well as being practical for frequency regulating elements for control of filter and generator circuits.

In a key impulse system of an electronic musical instrument the invention has the following advantages:

Complete avoidance of the disadvantages of metallic switch contacts and therefore the static switch voltages superposed upon the sound frequency voltage; independent individual regulability of the amplitude of the actuated sound frequency voltages during each moment of keying operating; in addition to low static, low expenditure and avoidance of large mechanical parts which would adversely affect sales of an instrument.

In addition the necessary decoupling resistors normally inserted in an electronic musical instrument can be dispensed with, because the individual elements in accordance with this invention require no decoupling resistances otherwise necessary for each individual contact element.

The number of necessary gas discharge tubes (in the simplest case common glow lamps) in accordance with the principles of this invention in an operative key impulse system corresponds to the number of otherwise necessary switch contacts or relays. Numerous technical embodiments exist for control of a gas discharge tube, breakdown of ionizable media, and the ionizing A.C. voltage field.

The various features of novelty which characterize this invention are particularly pointed out in the claims forming a part of this specification. For a better understanding of the invention, its operating advantages and specific object attained by its use reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

In the drawings:

FIG. 1 is an elevation of a keying system of a musical keyboard in accordance with the invention with the key in an operative condition to create sound;

FIG. 2 is the same elevation as FIG. 1 with the key in its inoperative position; and

FIG. 3 is a plan view of selected parts in FIG. 1.

Referring now to the drawings wherein like figures are used for like parts throughout, a key **10** is mounted for pivotal actuation by the finger of a player of the musical instrument. A second key **12** is adjacent thereto and similar to the black key on a piano keyboard. A projecting rod **14** normal to the underside of the key **10** is adapted to engage a spring sheet or leaf spring **16** mounted by means of bolt **18** and connected to ground. The spring sheet **16** is biased upwardly to retain the key **10** in the position shown in FIG. 2. Connected to the other end of the sheet spring **16** on its underside is a U-shaped metal shielding sheet or bus bar **20** adapted to move vertically with the spring sheet **16** within a path so that stationary objects may remain within the recess of a U-shaped sheet **20**. Disposed within the U-shaped sheet are shown three glow tubes **22, 24** and **26** in upstanding parallel arrangement to form a straight line. The tubes **22, 24** and **26** are adapted with electrodes **28** and **30, 32** and **34, 36** and **38**, respectively, and each is filled with an ionizable gas such as neon. The electrodes **28, 32** and **36** are connected to three sources of A.C. voltages of sonic frequency designated f_1, f_2 and f_3. Three capacitors **40, 42,** and **44** are respectively connected to the sources of voltage f_1, f_2, and f_3 and to ground and are adapted to be used as high-frequency filter passes to ground. Electrodes **30, 34** and **38** are respectively connected to outputs **46, 48** and **50** and to ground by means of three parallel capacitor resistor combinations which include capacitor **52** in parallel with resistor **54**, capacitor **56** parallel to resistor **58** and capacitor **60** parallel to resistor **62**. At the level of the gap between the electrodes **28** through **38** and straddling the three gas tubes **22, 24** and **26** is a forked exciter **64** comprised of two extended wires joined at one end and connected to a source of high-frequency voltage **65** adapted to ionize the gases in the glow tubes **22, 24,** and **26**. The frequency of the voltage is about 100 kilocycles at an A.C. voltage of about 500 volts. The sound frequency voltages at the input electrodes **28, 32** and **36** have an average value of 5 volts. This is intended to be well below the firing or maintaining voltage of the glow tubes **22, 24,** and **26**, which are similarly constructed, with axial electrodes that display a very small electrode capacitance. The spacing between the glow tubes and the extended exciting wires **64** is about 3 mm. on both sides. They produce a constant A.C. voltage field to continuously ionize the gas space between the electrodes. When the key **10** is depressed and in the position shown in FIG. 1, the spring sheet **16** is also depressed and the U-shaped shield **20** is displaced from the glow tubes and from the extended exciter **64**.

In its undepressed position, the spring sheet **16** lifts the shield **20** to a position between the exciter **64** and the glow tubes. The shielding sheet **20** in this position

has the effect of completely shielding the glow tube from the ionizing effect of the exciter **64**.

In operation, when the key **10** is depressed, the shield **20** is removed from the vicinity of the space between the electrodes **28** to **38** in the glow tubes **22**, **24** and **26** and the exciter **64** is capable of ionizing the gas in the glow tubes. There is a path from the sources of A.C. voltages of sound frequency which are arranged to emit a constant set of voltages through the glow tubes **22**, **24** and **26** to the outputs **46**, **48** and **50** across the resistances **54**, **58** and **62**, respectively. The capacitors **52**, **56** and **60** are substantially high-frequency by-passes but may be selected to affect the circuit. In its un-ionized condition, the gas in the glow tubes presents an extremely high impedance of approximately 100,000 ohms to any current which tends to pass from f_1, f_2 and f_3 to **46**, **48** and **50**, respectively. As the voltages f_1, f_2 and f_3 are insufficient to fire or maintain the glow tubes, the internal impedance remains high. When the gas in the glow tubes **22**, **24** and **26** is ionized, upon depression of the key **10** and removal of the shield **20** due to the excitation of the exciter **64** the internal impedance of the tubes are appreciably decreased. As a result, the voltages across the resistors **54**, **58** and **62** represent an appreciable fraction of the input voltages f_1, f_2 and f_3. Substantially the tubes here act as open and closed switches which allow the circuits from f_1, f_2 and f_3 to **46**, **48** and **50** to be completed so that the reproducing equipment in the musical instrument is capable of playing the sound selected. The values of the resistors **54**, **58** and **62** determine the magnitude of the voltages across them because of the voltage divider effect of the resistors and the tubes. The resistors are so arranged that a particular proportion of the desired sound output exists at a particular frequency.

The internal impedance of the glow tubes can vary with the degree of ionization after the field has fired the tubes. Thus the degree of movement of the key may, if small, allow only a small amount of ionization in the tubes and thus create a high internal impedance within the tubes and only a low output. In this way, the operator of this musical instrument is able to control the volume in a manner similar to a piano.

The value of the capacitors **52**, **56** and **60** determine the succession or order of occurrence of the sounds emitted by the system in response to the depression of the key **1**. This is so because the capacitors are in series with the internal impedances of the glow tube and act as impedances which may vary the succession of sounds produced by one key, and which vary with the condition of the internal impedance of the glow tubes. That is, if the internal impedance of one glow tube, during ionization, is comparatively low and its capacitance is comparatively high, the capacitor may tend to shunt a portion of the output until the internal impedance of that glow tube is lowered. The remaining capacitors may not be shunting their voltages during the high impedance interval.

Because the spring sheet or leaf spring **16** is mounted for movement about a point by the rivet **18**, the bus bar **20** will be moved from the space between the exciter **64** and the glow tubes much more quickly at the outer glow tube **26** than at the inner glow tube **22**. Thus, the outer glow tube **26** will tend to ionize more rapidly than the inner glow tube and the frequency voltage passed by the glow tube **26** will be more prominent than the other frequencies at the start of the stroke upon the key **10**. However, this is only a tendency and can be controlled by control of the capacitors **52**, **56** and **60**. Other things being equal, the tones depending upon the depression tempo will be sounded successively in proportion to their distance away from the pivotal mount **18**.

As the key is depressed, its appropriate tone is sounded with a gradual rise in amplitude. Further, its contents of harmonics gradually rise because of the capacitive reactance ratio of the capacitors **52**, **56** and **60** to the internal impedances of the glow tubes **22**, **24** and **26**.

It will be noted that the entire process as illustrated herein is practically inertialess and there is no static introduced as the result of metallic clicks or corrosion.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the invention principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In an electronic musical instrument having an alternating voltage source of sonic frequency, a keying system associated with said source, a gas discharge tube connected with said voltage source for providing a current path for said voltage source, said tube including an ionizable medium within said gas discharge tube, and a pair of electrodes within said gas discharge tube, said voltage source having a voltage output insufficient to maintain discharge in said tube connected across said electrodes, mean for producing a high frequency gas ionizing electric field in the gas discharge path in said tube, and means connected to said keying system and responsive thereto for selectively controlling the intensity of said high frequency field.

2. In an electronic musical instrument having a souree of alternating current voltage of sonic frequency, a keying system associated with said source of voltage, a gas discharge tube connected with said voltage source providing a path for current from said voltage source, said alternating current voltage being insufficient to maintain discharge in said gas discharge tube, means for producing a high frequency potential field in the discharge path of said gas discharge tube, said means producing a field of sufficient voltage and frequency to cause discharge in said gas discharge tube, and means responsive to said keying system selectively shielding said gas discharge path from said high-frequency producing means.

3. In an electronic musical instrument having a plurality of keys, a plurality of sonic frequency alternating current sources associated with each of said keys, a plurality of parallel spaced gas discharge tubes associated with each of said keys arranged to provide a current path from each of said sources, said gas discharge tubes having maintaining voltages in excess of the voltage of said atlernating current sources, high frequency voltage means for producing an ionizing field in the discharge path within said glow discharge tubes, and a plurality of shielding means each responsive to one of said keys movably mounted between said high frequency voltage means and said glow discharge tubes to selectively regulate the degree of ionization within said glow discharge tubes.

4. In an electronic musical instrument as set forth in claim 3, a resistor in series with each of said glow discharge tubes connected to ground to form with said tubes voltage divider networks wherein the outputs are taken across said resistors.

5. In an electronic musical instrument as set forth in claim 3, each of said shielding means including a spring for upwardly biasing one of said keys and a metallic sheet mounted on said spring, located between said high-frequency voltage means and said glow discharge tubes.

6. In an electronic musical instrument as set forth in claim 5, a projection on each of said keys engaging said spring for selectively moving said shielding member from the space between said high frequency voltage means and said glow discharge tube.

7. In an electronic musical instrument having a plurality of keys adapted to be depressed and initiate musical tones, a plurality of sound sources associated with each of said keys, a plurality of glow discharge tubes including an ionizable medium, a pair of electrodes mounted in each of said tubes and a discharge path separating said electrodes, each of said discharge tubes being connected to one of said sources of sound, said sources of sound pro-

ducing alternating current voltages of sonic frequency at first electrodes of said pair of electrodes in said glow discharge tubes, said voltages being of a magnitude insufficient to maintain discharge in said gas-discharge tubes, high frequency by-passes connected from said first electrodes of said gas discharge tubes to ground, a plurality of resistors each connected to second electrodes of said pairs of electrodes in said gas discharge tubes, to form a voltage divider network with said discharge tubes to ground, by-pass capacitors for said plurality of resistors, high frequency exciting means of sufficient frequency and magnitude to produce ionization in said glow discharge tubes disposed adjacent said glow discharge tubes to produce ionization of said ionizable medium in said glow discharge tubes, a plurality of leaf springs mounted at one end adapted to bias each of said keys upwardly, a plurality of projections each on said keys in contact with said spring, and a U-shaped shielding sheet secured to said spring for positioning between said exciting means and said plurality of glow discharge tubes associated with

each of said keys when said key is in its biased ineffective position, said shielding sheet being selectively movable from between the space between said exciting means and said glow discharge tube to a plurality of less effective shielding positions upon movement of said key and said sheet spring to an effective position whereby a discharge is produced in said gas discharge tubes and the internal impedance of the gas discharge tube is varied.

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