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3,333,041

KEYING SYSTEMS FOR ELECTRICAL MUSICAL INSTRUMENTS FOR PRODUCING
STEADY-STATE OR PERCUSSIVE TYPE TONES EITHER
SEPARATELY OR CONCURRENTLY

Filed July 9, 1965

2 Sheets-Sheet 1

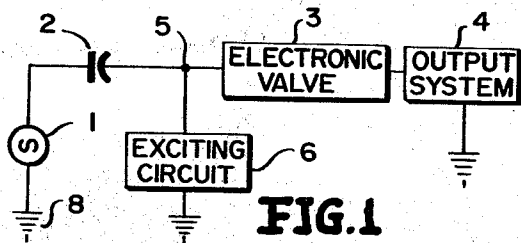


FIG. 1

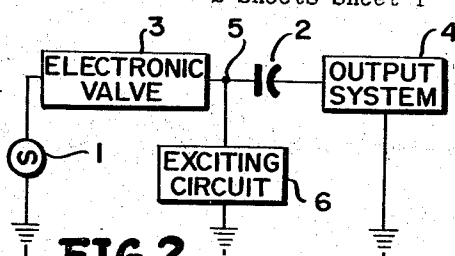


FIG. 2

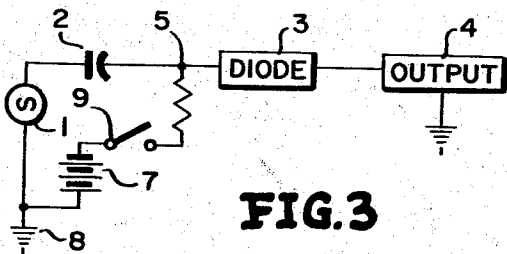


FIG. 3

FIG. 3a FIG. 3b

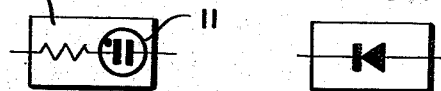


FIG. 3c

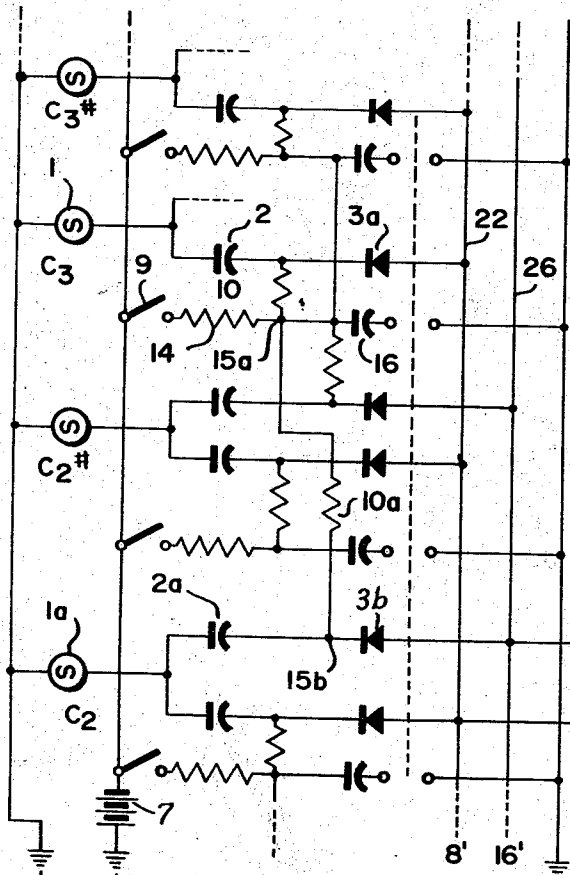


FIG. 5

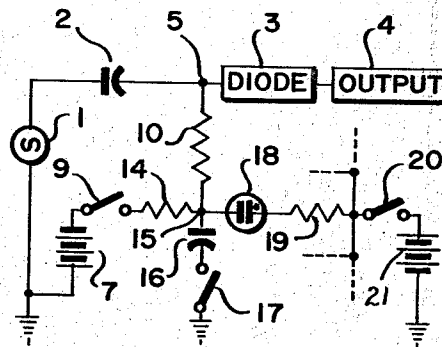
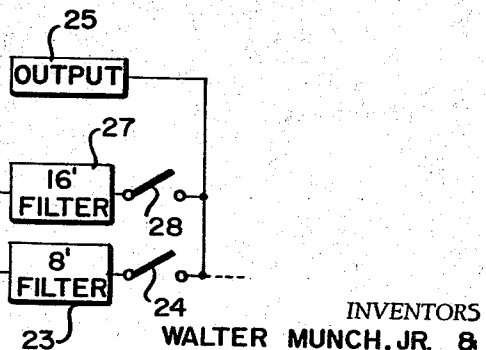


FIG. 4



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FIG. 6

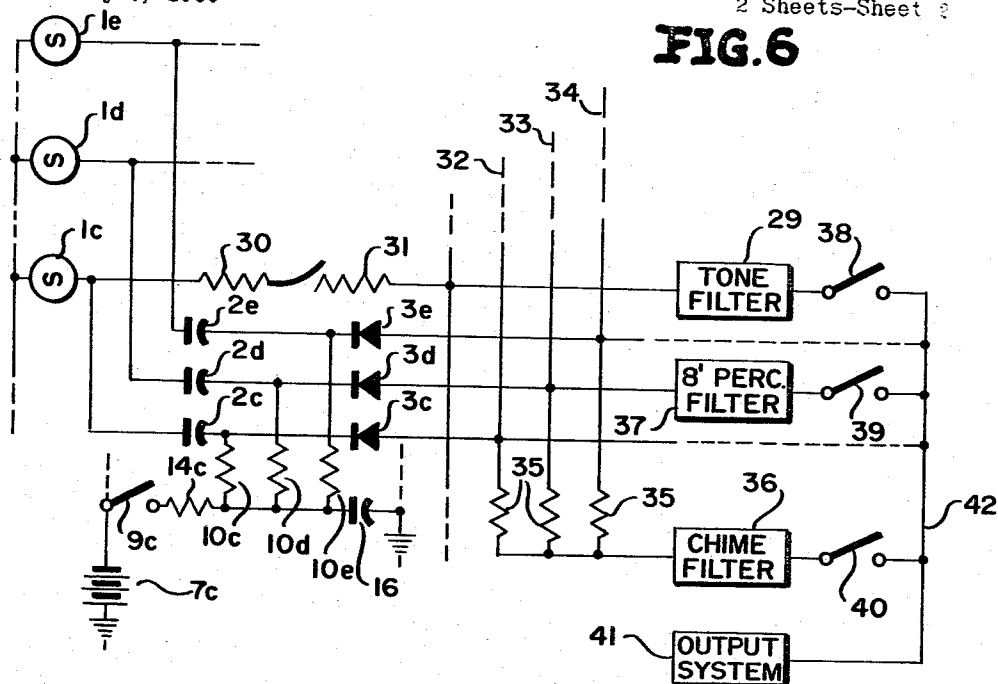
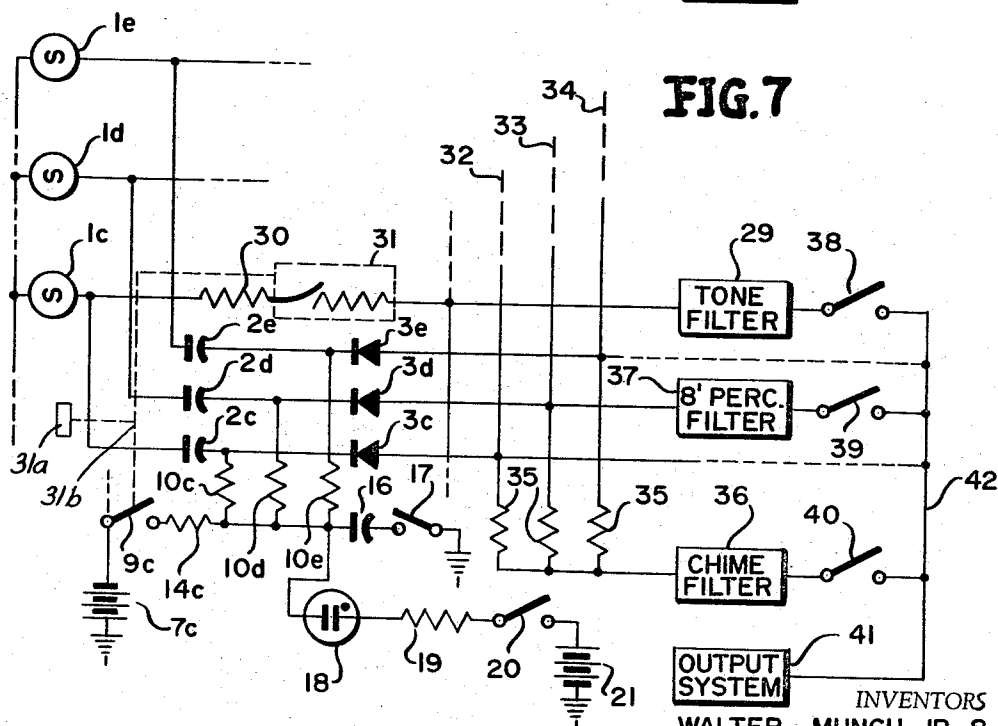


FIG. 7



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KEYING SYSTEMS FOR ELECTRICAL MUSICAL INSTRUMENTS FOR PRODUCING STEADY-STATE OR PERCUSSIVE TYPE TONES EITHER SEPARATELY OR CONCURRENTLY

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Filed July 9, 1965, Ser. No. 470,859
15 Claims. (Cl. 84-1.11)

This application is a continuation-in-part of our application Ser. No. 135,101, filed Aug. 28, 1961, now U.S. No. 3,223,768, and entitled, "Keying Systems for Electrical Musical Instruments."

This invention relates to keying systems for electrical musical instruments, by means of which continuously produced audio signals corresponding to musical tones can be selected, as desired, for transmittal to an output system. The term output system as used herein should be understood, without other qualification, as including collecting and tone coloring circuits, amplifying and reproducing means. More specifically, the invention has to do with improved keying circuits employing simple, bi-terminal electronic valves commonly known as diodes, usually rendered conductive to an audio signal by the application of direct current potentials by means of key actuated make-break switches.

The diodes used in prior art systems have taken various forms, which may be classified as (1) vacuum diodes (2) solid-state diodes including varistors and (3) gaseous discharge devices, such as type NE-2 neon tubes. U.S. Patent 2,483,823, to George falls in the first category, while Rienstra 2,486,208 is in the second group. The third class is inclusive of Faulkner 2,811,069, Anderson et al. 2,811,887 and Anderson 2,823,310. Certain inherent disadvantages, from a commercial standpoint, have been present in various ones of the named systems. These include (1) the necessity for separate bias sources to maintain diodes non-conductive, (2) the presence of undesired D.C. keying transients in output systems during charging of coupling capacitors, (3) presence of signal feed-through in output systems when diodes are not being keyed, and (4) the use of many and/or expensive circuit components.

In view of the above named factors, it is a primary object of this invention to provide a keying circuit not requiring a separate bias source to maintain the diode in a non-conductive state.

It is a further object to provide such a circuit which will be free from undesired D.C. keying transients.

It is an important object to provide a keying circuit having a high signal-to-feed-through ratio.

It is a still further object to provide a simple, low cost keying circuit suitable for use, for example, in electronic organ systems requiring several such circuits per playing key.

In U.S. Patent 2,986,984 to Bissonette and Kramer, there is disclosed an electronic musical instrument, wherein both steady state tone (of the type associated with a pipe organ) and "percussive" type tones may be derived separately or simultaneously, the latter type tones becoming apparent in staccato playing, and the former type having an effect only upon the initial, or key down portion of the tone when percussive effects are being achieved. The teachings of the present invention may, for example, be employed in instruments of the Bissonette-Kramer type, for either or both keying systems. In other words, this invention in one facet may be used in the place of variable resistance key switches of the Kock-Jordan type, for example, as disclosed in their U.S. Patent 2,215,124, to obtain steady state tones. In another facet, percussive effects may be achieved in the manner, for example, disclosed in

the Bissonette-Kramer case or in the U.S. Patent 2,918,576 to Munch. Both latter patents disclose vacuum triode gate circuits having means to cause gradual decay of the tones. Thus, it is an important object of this invention to provide improved, low cost keying circuits suitable for separate or concurrent use in obtaining steady state and/or percussive type tones.

The advent of transistors in generating circuits for electronic organs has lead to low cost frequency dividers of a "flip-flop" type, whose output is characterized by square waves. This development has made attractive organ systems of the type disclosed in U.S. Patent 2,571,141 to Knoblauch and Jordan, wherein musical signals of complex, but symmetrical wave form (characterized by a deficiency or absence of even order harmonics), are combined after keying and controlled as to amplitude in such manner as to provide tones having both even order and odd order harmonics. The multiple signal keying required in such a system for steady state tones can be accomplished by conventional keying means or in accordance with the teachings of this invention. However, if percussive type tones having a full complement of harmonics are to be derived from the same symmetrical wave generating circuits as those supplying the steady state tones, it is a distinct advantage to be able to perform the keying function for the percussive tones with a single make-break switch. It is therefore an important object of a preferred embodiment of the present invention to provide simple, low cost keying circuits capable of producing a wide range of percussive type voices in an electronic organ employing square wave generators.

It is a further object of the invention to provide improved keying circuits for use in electric musical instruments having continuously operating generators of other than square wave.

A primary object of this invention is to provide keying circuits which not only obviate the use of variable resistance key switches in producing conventional type organ tones, with envelopes as desired, but, also will make available so-called "sustain" characteristics to the tones.

It is a still further object of the invention to provide a low cost keying system such that chime or carillon type tones may be obtained.

The objects of the invention set forth above, and others which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, are accomplished in that construction and arrangement of parts of which certain exemplary embodiments will now be described. Reference is made to the accompanying drawings, wherein:

FIGURE 1 illustrates a circuit diagram, partly in block form, of a preferred embodiment of this invention;

FIGURE 2 shows a similar diagram of an alternate form of the invention;

FIGURE 3 is a schematic illustration, partly in block form, showing some detail as to an exciting circuit for the diode section of a keying system in accordance with this invention;

FIGURES 3a, 3b and 3c illustrate respectively three different forms which the diode section of the system of this invention can take;

FIGURE 4 is a schematic illustration of the system of FIGURE 3 expanded to include portions affecting the decay of tones produced by this invention;

FIGURE 5 is a schematic diagram showing the application of keying circuits to an organ system of the type wherein octavely related oscillations are keyed into separate collectors for different footages;

FIGURE 6 illustrates the application of keying circuits in accordance with this invention to a system for producing tones simulating chimes and the like;

FIGURE 7 is a circuit diagram illustrating a modification of the system of FIGURE 6 adding thereto certain functions available in FIGURE 4.

A preferred basic form of this invention is shown in FIGURE 1, wherein a continuous signal corresponding to a musical tone is derived from a suitable source 1 via a coupling capacitor 2, for application to a bi-terminal electronic valve, such as a diode, designated by the block 3. An appropriate output system 4, which may comprise, broadly, collecting and tone coloring means, a conventional amplifier and loudspeaker or other electroacoustic means is shown connected to the diode. To the point 5 is shown connected a block 6 representing an exciting circuit for the diode section 3. The nature of the diode will be discussed hereinafter, together with the characteristics of the exciting means indicated at 6. As the specification proceeds, it will become obvious that the requirements of a particular circuit will dictate whether the exciting circuit merely performs an on-off function with respect to the diode or whether the exciting circuit will produce in the output system 4 a tone envelope of a particular shape, such as one with the trailing decay characteristic of a percussive type tone.

An alternate form which this invention, in certain aspects, may take, is illustrated in FIGURE 2, wherein corresponding elements are similarly designated. The first of the two circuit loops connected across the source 1 of FIGURE 2 comprises the diode 3, the capacitor 2 and the output system 4, as in FIGURE 1, although the order of the diode and capacitor is reversed. The second of the circuit loops connected across the source 1 in FIGURE 2 comprises only the diode 3 and exciting circuit 6. In both figures the two circuit loops may be closed, as shown, by a common return path represented by the conventional ground symbol.

As will be explained in greater detail hereinafter, the tone signal from the continuously operating source 1 of FIGURES 1 and 2 is transmitted to the output system when the diode 3 is changed by the exciting circuit 6 from a state of substantially zero conductivity to one of appreciable conductivity.

Reference is now made to FIGURE 3, the circuit of which is similar to that of FIGURE 1, except that a simple D.C. exciting path is shown. Corresponding elements of the circuit are similarly designated and connected. The exciting circuit of FIGURE 3 comprises a D.C. source 7 connected at one side to a common return 8 and at its other side to a single-pole, single-throw switch 9, which, in a closed position, can apply the D.C. potential to the point 5 via a resistor 10. Although the diode 3 may take several forms, a preferred one in this invention being one of a solid state type, shown by the appropriate symbol in FIGURE 3b, certain teachings of this invention may also be applied using diodes of a gaseous discharge type, indicated in FIGURE 3a at 11, in series with a relatively high resistance 12. It will be obvious that a vacuum diode, indicated at 13 in FIGURE 3c, can also be used to practice the teachings of the invention; although for economic reasons a solid state or gaseous diode may be preferred. A prime requisite, however, for all diodes used to practice certain teachings of this invention, is that they be characterized by one state of substantially zero conductivity and another state of appreciable conductivity with a positive resistance characteristic. Vacuum diodes and solid state diodes currently available already meet such a requirement. However, in the circuit configurations disclosed herein, a gaseous diode, such as type NE-2, must have in series therewith a relatively high resistance—say 5 megohms—sufficient to give a substantial portion of its current versus voltage characteristic curve a positive slope. Such a keying circuit has already been disclosed, for use in a system for keying harmonically related signals through a common gate, in a co-pending application, Ser. No. 40,232, filed July 1, 1960 by the same assignee, entitled Gating System for Electrical Musical Instrument,

in the name of Alfred J. Bissonette and one of the present inventors, Walter Munch, Jr. (now Patent No. 3,176,060). This assures that the gaseous diode will conduct throughout the audible portion of a gradual decay characteristic in, for example, percussive type tones, circuits for which will be discussed hereinafter.

In the circuit of FIG. 3, the build-up and decay of the tone are affected by the size of the coupling capacitor 2, that is the larger the capacitance, the slower the rate at which the tone develops and dies away. However, the configuration of FIG. 1 may be preferable to that of FIG. 2, because in the latter the D.C. charging current to the capacitor 2 must flow through the output system 4 and may cause objectionable transients therein.

Reference is now made to FIG. 4 for the manner in which the decay of the tones can be controlled, although it will be understood that the tone build-up may also be affected to some extent in FIG. 4. In FIG. 4, similar portions of the two circuits are similarly designated and connected, there being an additional resistor 14 in series with the resistor 10 through which the exciting voltage from the source 7 is applied to the diode 3 at the junction 5. Between the junction point 15 and a common return path are connected a decay capacitor 16 and a single-pole, single-throw switch 17 which may be controlled by a stop tab. Also connected to the junction point 15 is a gaseous diode 18, which, by way of example, may be a commonly known type NE-2E, in series with a resistor 19, another single-pole, single-throw switch 20 and a second D.C. source 21.

When it is desired to impose a gradual decay upon a signal keyed by the switch 9, the switch 17 must be closed prior to keying, thus bringing the capacitor 16 into the circuit. As the switch 9 is closed, voltage from the D.C. source 7 charges the capacitor 16 at a rate determined by the resistor 14 and the capacitor 16. Thus, the build-up of the voltage at the point 5, which determines the rate at which the signal from source 1 is gated to the output system 4, is affected by the time constant of the capacitor 16 and resistor 14, as well as by the coupling capacitor 2 mentioned above. The selection of these tone build-up components—i.e., resistors 14 and 10, capacitors 16 and 2—can be made in accordance with electrical design principles to achieve the desired onset to a particular tone.

Upon opening of the switch 9 (assuming switch 17 closed), the charge on the capacitor 16 is dissipated in the resistor 10, diode 3 and output system 4, at a rate determined by the time constant of the combined elements. Should a shortened rate of decay of the tone be desired, it can be accomplished by the "short sustain" circuit comprising, for example, the gaseous diode 18, resistor 19, switch 20 and D.C. source 21, as taught in a copending application of the same assignee entitled Keying System for Electrical Musical Instruments, Ser. No. 4,444, filed Jan. 25, 1960, in the name of Walter Munch, Jr.

The voltage of the D.C. source 21 is substantially the same as the breakdown voltage of the diode 18 so that, upon actuation of the switch 9 and the firing of the diode 18 (voltages of D.C. source 7 and 21 being additive), the capacitor will discharge upon opening of switch 9, to a level where the voltage at point 15 is substantially zero (at which point the diode 3 approaches non-conduction) before the diode 18 ceases to conduct. It will be obvious to one skilled in the art that the parallel path furnished by the diode 18 circuit will allow the capacitor 16 to discharge at a faster rate, resulting in a shorter decay time for the note keyed into the output system 4.

Although a mere duplication of the circuits of FIGS. 3 or 4 will provide simple systems for playing a plurality of notes for polyphonic music, the system of FIG. 5 illustrates an assembly employing but one switch per key, which will enable a musician to play a "16 foot" voice, for example, simultaneously with an "8 foot" voice, as is

currently accomplished in commercially available organs using multiple "gradual contact" key switches.

Certain keying systems will now be described in connection with FIGS. 5 and 6. In these figures the conventional symbol for a solid state diode has been used; but it will be understood that any of the diodes illustrated or indicated in FIGS. 3a, 3b and 3c may be substituted.

Any of the known solid state diodes which respond to the requirements hereinabove set forth are available for the purposes of this invention. Without limitation, selenium diodes are preferred because they may be made cheaply. They may also be made in ganged formation as taught in U.S. Patent 3,179,855 to John B. Brombaugh, entitled, Mounting Means for a Diode Assembly, issued Apr. 20, 1965.

Considering in FIG. 5 the key circuit for a source 1 for note C₃, components corresponding to those of FIG. 4 are similarly designated and connected. The output of diode 3a is connected to a collector 22, for all 8' signals, to which is connected, as is known in the art, a tone color filter 23 of the type, for example, disclosed in the Kock Patent 2,233,948. A selector switch 24 preferably actuated by a conventional stop tab (not shown) serves to direct the modified tone signals to a suitable amplifier and loudspeaker system, designated by the block 25. Other teachings of Kock in the mentioned patent, such as those pertaining to out-phasing, may obviously be included, if desired.

To the point 15a, corresponding to the junction 15 of FIG. 4, is connected a resistor 10a for transmission of D.C. from the common source 7 to a point 15b in a keying circuit of similar character, comprising coupling capacitor 2a and diode 3b coupled, as shown to generator 1a of a continuous wave at a frequency corresponding to note C₂. Thus, it will be seen that a signal an octave below that of the signal transmitted to the 8' collector 22 will be keyed into a collector 26, which is designated 16' in accordance with standard organ terminology. A 16' tone-color filter 27 is shown as modifying the output of the collector 26 for transmittal to the output system 25 via a stop tab controlled switch 28. Thus, with a simple make-and-break switch 9 (FIG. 5), a plurality of signals of different "footages" can be keyed into different headers; whence they can be modified as to timbre, added together, added in out-of-phase relationship and passed to an output system. Since the onset of the tones can be controlled by the circuit components as previously discussed, mechanical "gradual contact" switches need not be used; only one switch need be used with each key, and a long-life substantially service free system can be achieved.

The keying circuits of this invention can be further utilized to achieve chime and carillon effects in an electric musical instrument.

In FIG. 6, a source 1c of continuous tone signals may supply a tone-color filter 29 of conventional design via a conventional decoupling resistor 30 and resistive key switch 31 for steady state organ type tones. If desired, this keying circuit may be of the type previously disclosed herein in FIG. 4, for example, or even FIG. 5, if full exploitation is to be made of the teachings of this invention. In any event, chime or carillon tones and, if desired, conventional percussive effects may be achieved concurrently. While source 1c is supplying conventional organ type tones, with or without "sustain" of the nature disclosed in FIG. 4, it may also be sending its output via coupling capacitor 2c to a keying diode 3c of, for example, a solid state type. Gating voltage for the diode 3c may be furnished from a common source 7c via switch 9c, resistor 14c and resistor 10c as shown. Similarly, keying voltage may concurrently be supplied to diode 3d and 3e via resistors 10d and 10e, respectively, from resistor 14c which has been energized by switch 9c from the source 7c. Consequently signals from source 1c, previously mentioned, and from harmonically related con-

tinuous wave sources 1d and 1e as coupled into the named keying circuits by coupling capacitors 2d and 2e, respectively, concurrently appear on collectors 32, 33 and 34 respectively. In accordance with known musical teachings, appropriate amplitude harmonic components are synthesized by a suitable resistive summing network 35 into a composite chime or carillon type tone for modification, if desired, by an appropriate filter 36. Switches 31 and 9c may be operated by a common key 31a, the required mechanical coupling between switch 31, switch 9c and key 31a being indicated by dotted lines 31b.

If desired further, a conventional "percussive" tone, such as a "vibraharp," may be produced by passage of a signal from one collector 33, for example, through a suitable filter 37.

Thus, should the performer on an instrument of the type outlined in FIG. 6 desire to produce tones of conventional organ character, or of general percussive nature, or of chimes, for example, he could, by actuation of stop switches 38, 39 or 40, respectively, derive the tones from a conventional output system 41, the signals having been collected by a bus 42 for the subsequent conversion to sound. The percussive and chime tone would, of course, be achieved by staccato type playing of the keys. Also, in accordance with the teachings of the aforementioned Bissonette-Kramer patent, the key-down portion of the tones could be varied in color by concurrent use of the steady state tone circuit by actuation of stop switch 38.

It will be understood in FIG. 6 that the resistive switch 31 and the make-and-break percussive switch 9c are coupled, i.e., they are actuated by the same playing key. Also, it will be understood by those familiar with electric organs that there may be other resistive switches similar to 31 connected to other harmonically generators and to separate headers, such switches also being coupled to the same playing key, so that upon the depression of such key, harmonically related oscillations may be simultaneously derived in different headers.

While FIG. 6 shows circuits for the derivation of steady state oscillations (ordinary organ tones) from generators by resistance-coupled gradual contact switches, it will be evident from FIG. 5 how capacitatively coupled diode circuits using only a single make-and-break switch can be used instead of circuits employing gradual contact switches. Thus it becomes possible to construct an entire organ employing but two simple make-and-break switches per key, but deriving simultaneously a plurality of different oscillations in different headers both in the steady state system of the instrument and in the percussive system thereof.

In FIGURE 7 the gating circuit of FIGURE 4 is incorporated into the system of FIGURE 6, in order to provide for elimination of the storage capacitor 16 from circuit by opening switch 17, and for incorporating a short sustain provision by incorporating diode 18 and its control circuitry.

Throughout these specifications numerous omissions of extraneous material have been made in the interests of simplification of the diagrams and descriptions thereof. An example of this lies in the tone color circuits of certain figures, wherein only one block has been shown. It will be understood that a plurality of output systems may be used, as required for example, one for steady state and one for percussive type tones. Thus many modifications may be made in the invention without departing from the spirit of it. The invention having been described in certain exemplary embodiments, what is claimed as new and is desired to be secured by Letters Patent is:

1. In an electronic organ,
- a plurality of three continuously running tone sources for producing organ tone,
- paths extending from each of said tone sources,
- each of said paths including a separate solid state diode gate connected in cascade with one of said tone sources,

an electro-acoustic load circuit connected in cascade with all said gates, means for normally maintaining all said solid state diode gates non-conductive, a source of direct bias voltage, key switch means including only two switch contacts interposed between said source of direct bias voltage and all said solid state diode gates, a single operating key for said key switch means, the operating key being operable to close said key switch means on depression of said key, the polarity and amplitude of said direct bias voltage being selected to render all said solid state diode gates conductive to the outputs of said tone sources on actuation of said single key, whereby tone derived from all said tone sources is applied to said electro-acoustic load circuit on actuation of said single key.

2. The combination according to claim 1 wherein said tone sources include means which render them harmonically related.

3. The combination according to claim 2, wherein is provided

a storage capacitor connected in charging relation to said source of direct bias voltage via said key switch means,

a long time constant discharge circuit means for said storage capacitor,

one terminal of said storage capacitor being permanently connected to all said gates in such relation that its charge tends to maintain said solid state diode gates all conductive, and said long time constant being sufficiently long to provide an audible tone sustain on raising of said key.

4. The combination according to claim 3 wherein is provided means including a diode device for selectively modifying the discharge time of said storage capacitor, and

means for selectively and at will connecting and disconnecting said diode device from said discharge circuit.

5. In an electronic organ,

a plurality of three continuously running tone sources for producing organ tone,

paths extending from each of said tone sources,

each of said paths including a solid state diode gate

connected in cascade with one of said tone sources,

an electroacoustic load circuit connected in cascade with all said solid state diode gates,

means for normally maintaining all said solid state diode gates non-conductive,

a source of direct bias voltage,

means applying said direct bias voltage to all said solid state diode gates simultaneously, the polarity and amplitude of said bias voltage being selected to render said solid state diode gates all fully conductive to the outputs of said tone sources, said tone sources being harmonically related,

a single storage capacitor connected to corresponding electrodes of each of said solid state diode gates and in charging relation to said source of direct bias voltage,

a long time constant discharge circuit means for said capacitor, said storage capacitor being permanently connected to all said gates in such relation that its charge tends to maintain said solid state diode gates all conductive and said long time constant being sufficiently long to provide an audible tone sustain on cessation of said direct bias voltage.

6. The combination according to claim 5 wherein is further provided means for weighting the relative amplitudes of the tones passed by said solid state diode gates so as to provide a chime tone.

7. The combination according to claim 5 wherein is further provided means for selecting one only of the

three tones passed by said solid state diode gates and suppressing the remainder of said tones, said last means comprising a filter connected in cascade with one only of said gates.

8. The combination according to claim 5 wherein is further provided a separate tone collection bus connected to each of said solid state diode gates for collecting the tones individually passed by said solid state diode gates.

9. The combination according to claim 5 wherein each of said solid state diode gates includes at least one solid state diode in cascade with an off-biasing capacitor and one of said tone sources, whereby rectified currents derived from said tone source and stored in said off-biasing capacitors normally maintain said solid state diodes non-conductive.

10. The combination in accordance with claim 9 wherein said means applying said direct bias voltage to all said solid state diode gates simultaneously includes a separate time constant resistance connected between said single source of direct bias voltage and the junction points of said off-biasing capacitor and said at least one solid state diode of each of said solid state diode gates, said time constant resistances being selected to provide a gradual build up of conductivity of said solid state diode gates.

11. In an electronic organ,

a plurality of continuously running tone sources for producing organ tone,

paths extending from each of said tone sources,

each of said paths including a separate solid state diode gate connected in cascade with one of said tone sources,

an electro-acoustic load circuit connected in cascade with all said gates,

means for normally maintaining all said solid state diode gates non-conductive,

a source of direct bias voltage,

a key switch means including only two switch contacts interposed between said source of direct bias voltage and all said solid state diode gates,

a single operating key for said key switch means, the operating key being operable to close said key switch means on depression of said key,

the polarity and amplitude of said bias voltage being selected to render said solid state diode gates all conductive to the outputs of said tone sources on closure of said key switch means, whereby tone derived from all said tone sources is applied to said electroacoustic load circuit on actuation of said single key.

12. The combination according to claim 11 wherein said tone sources include means which render them harmonically related.

13. The combination according to claim 12 wherein is provided

a storage capacitor connected in charging relation to said source of direct bias voltage via said key switch means,

a long time constant discharge circuit means for said storage capacitor,

one terminal of said storage capacitor being permanently connected to all said gates in such relation that its charge tends to maintain said solid state diode gates all conductive, and said long time constant being sufficiently long to provide an audible tone sustain on opening of said key switch.

14. The combination according to claim 13 wherein is provided means including a diode device for selectively modifying the discharge time of said storage capacitor, and

means for selectively and at will connecting and disconnecting said diode device from said discharge circuit.

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15. In an electronic organ,
 a plurality of continuously running tone sources for
 producing organ tone,
 paths extending from each of said tone sources,
 each of said paths including a solid state diode gate 5
 connected in cascade with one of said tone sources,
 an electroacoustic load circuit connected in cascade
 with all said gates,
 means for normally maintaining said solid state diode
 gates all non-conductive, 10
 a source of direct bias voltage,
 means applying said direct bias voltage to all said
 solid state diode gates simultaneously, the polarity
 and amplitude of said direct bias voltage being se-
 lected to render said solid state diode gates all con-
 ductive to the outputs of said tone sources, said
 tone sources being harmonically related, 15
 a single storage capacitor connected to corresponding

10

electrodes of each of said solid state diode gates
 and in charging relation to said source of direct bias
 voltage,
 a long time constant discharge circuit means for said
 capacitor, said storage capacitor being permanently
 connected to all said gates in such relation that its
 charge tends to maintain said solid state diode gates
 all conductive and said long time constant being
 sufficiently long to provide an audible tone sustain
 on cessation of said direct bias voltage.

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ARTHUR GAUSS, *Primary Examiner.*

J. S. HEYMAN, *Assistant Examiner.*