Dec. 14, 1965 W. MUNCH, JR., ET AL 3,223,768

KEYING SYSTEMS FOR ELECTRIC MUSICAL INSTRUMENTS

Filed Aug. 28, 1961 3 Sheets-Sheet 1

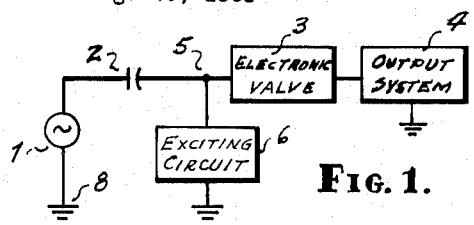


FIG. 1.

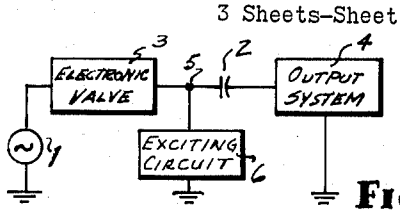


FIG. 2.

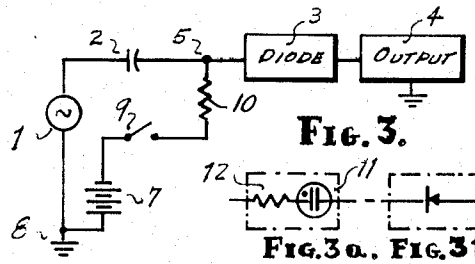


FIG. 3.

FIG. 3a., FIG. 3b.



FIG. 3c.

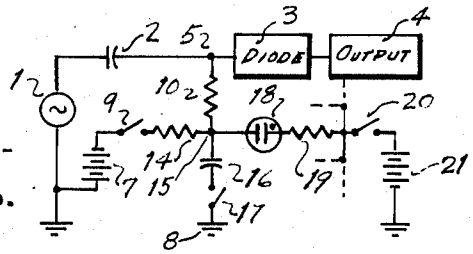


FIG. 4.

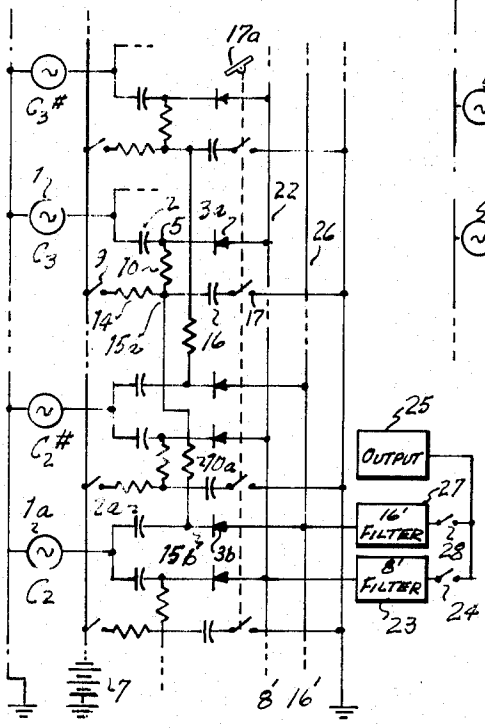


FIG. 5.

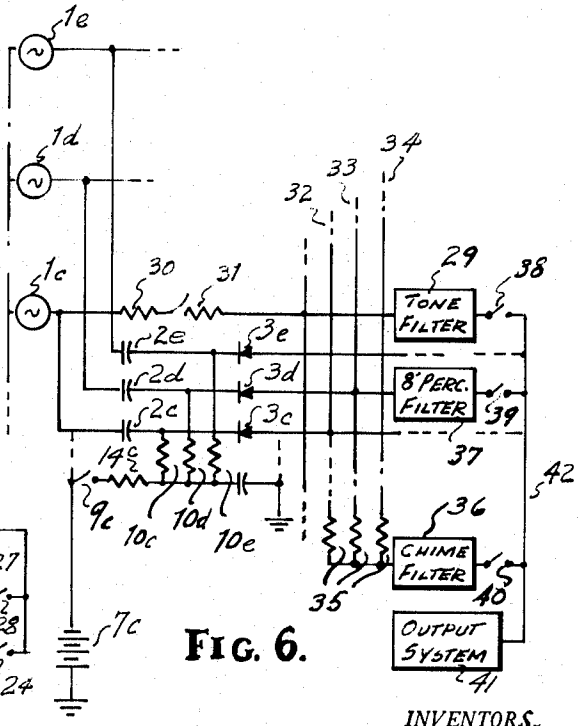


FIG. 6.

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KEYING SYSTEMS FOR ELECTRIC MUSICAL INSTRUMENTS

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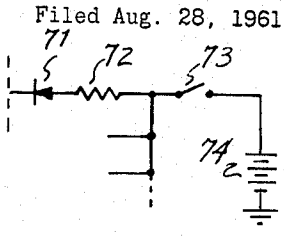


FIG. 8a.

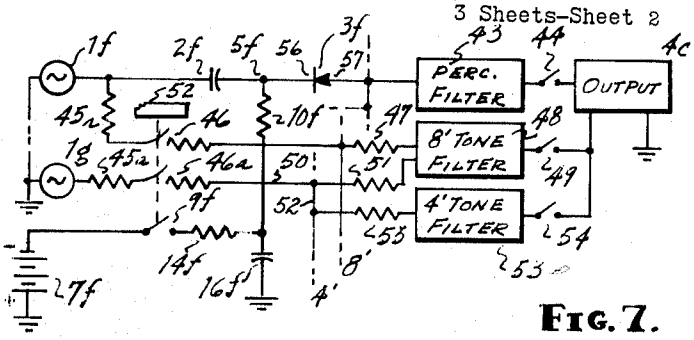


FIG. 7.

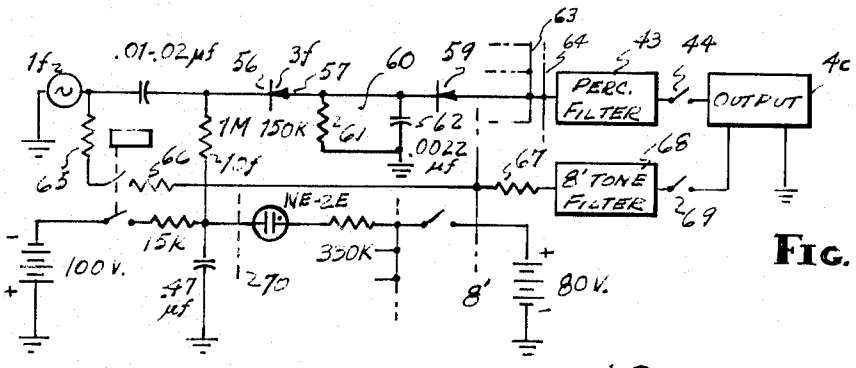


FIG. 8.

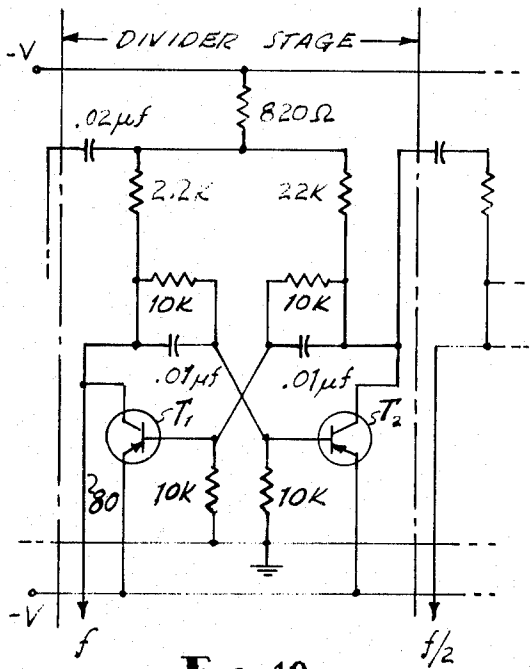


FIG. 10

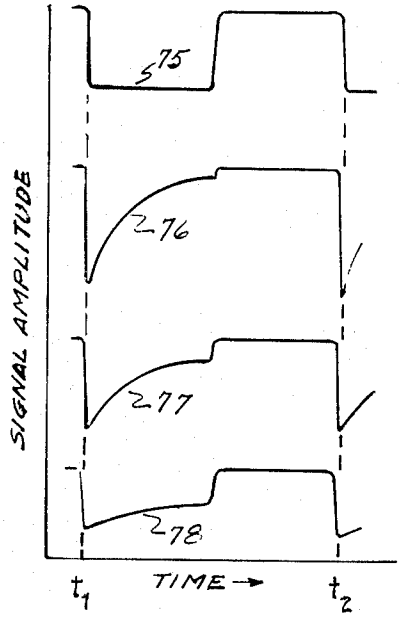


FIG. 9.

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KEYING SYSTEMS FOR ELECTRIC MUSICAL INSTRUMENTS

Filed Aug. 28, 1961 3 Sheets-Sheet 3

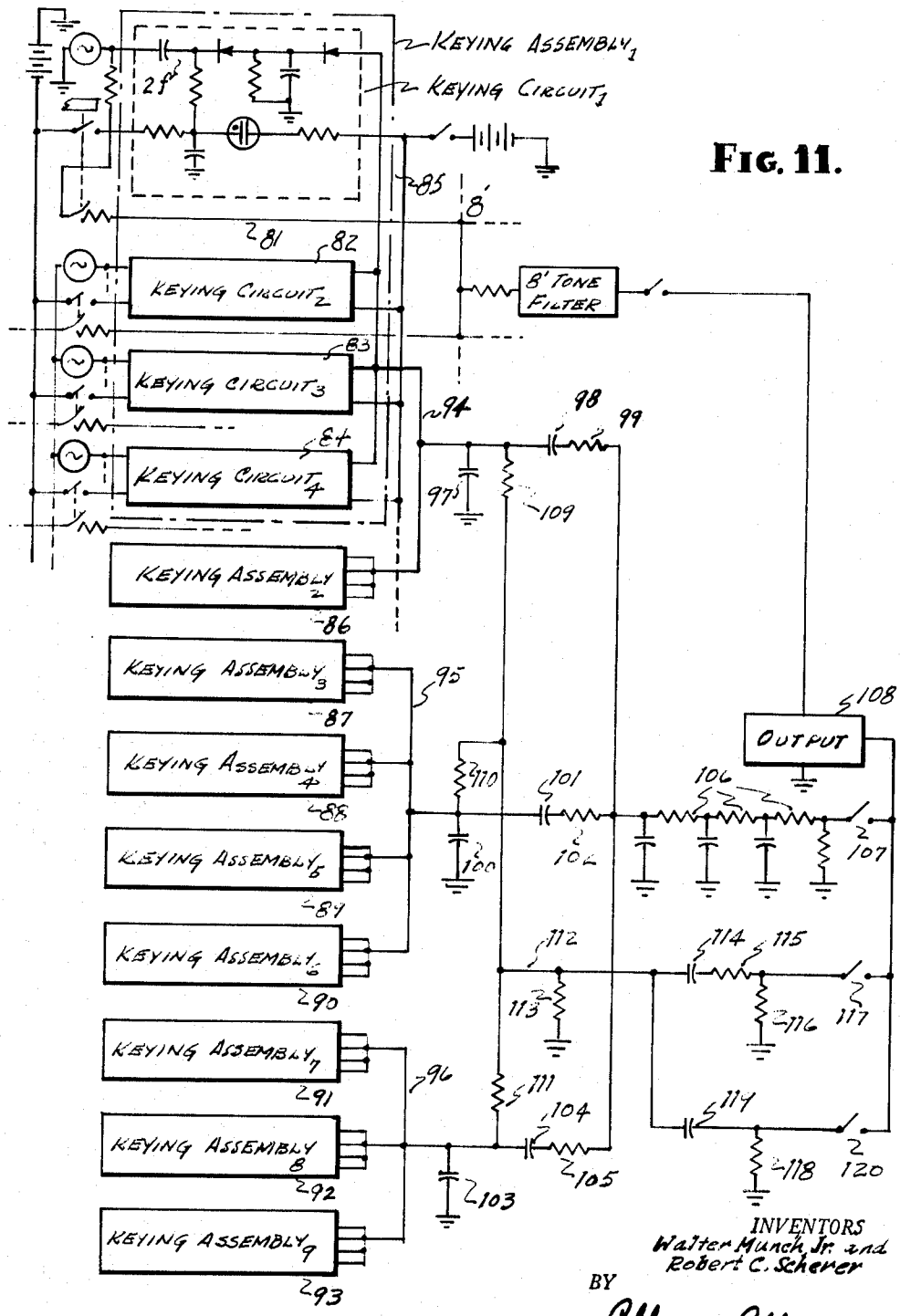


FIG. 11.

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KEYING SYSTEMS FOR ELECTRIC MUSICAL INSTRUMENTS

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Filed Aug. 28, 1961, Ser. No. 135,101
36 Claims. (Cl. 84—1.01)

This invention relates to keying systems for electric musical instruments, by which systems continuously produced audio signals corresponding to musical tones are selected, as desired, for transmittal to an output system. The term output system as used herein should be understood, without other qualification, as inclusive of collecting and tone coloring circuits as well as 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 playing 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 devices, such as 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 the 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 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 2,986,964 to Bissonette and Kramer, there is disclosed an electronic musical instrument, wherein both steady state tones (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 tridode 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 led 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 Knoblaugh 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 electrical musical instruments having continuously operating generators of other than square waves.

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.

An important object of this invention is to provide a keying system having a wave shaping function in converting square waves to waves of a generally sawtooth configuration. It is a related object of the invention, useful for scaling purposes, to provide a keying circuit by which the shape of output waves, from a square wave generator, may be determined by the choice of the coupling capacitance in series with the active elements in the circuit.

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:

FIG. 1 illustrates a circuit diagram, partly in block form, of a preferred embodiment of this invention.

FIG. 2 shows a similar diagram of an alternate form of the invention.

FIG. 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.

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

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

FIG. 5 is a schematic and block 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.

FIG. 6 is a schematic diagram illustrating the application of keying circuits in accordance with this invention to a system for producing tones simulating chimes and the like.

FIG. 7 is a schematic and block diagram illustrative of an embodiment of this invention providing a percussive keying circuit for use with a system of the Knoblaugh-Jordan type mentioned above.

FIG. 8 is a schematic and block diagram illustrating a preferred form of percussive keying circuit, together with provision for changing the rate of decay of the percussive tones, together with keying means for steady state type tones.

FIG. 8*a* is a schematic and block diagram illustrating a variation or alternative to one portion of the circuit of FIG. 8.

FIG. 9 is a graph illustrating an input wave and three types of wave forms which may be achieved at the output of keying circuits in accordance with the teachings of this invention.

FIG. 10 is a schematic diagram representing one divider stage in a generator circuit of a type suitable for use with this invention.

FIG. 11 is a schematic and block diagram illustrating a complete system, partly schematic and partly block, for providing percussive tones of different character in an electronic organ having keying circuits also for steady state type tones.

A preferred basic form of this invention is shown in FIG. 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 electro-acoustic 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 FIG. 2, wherein corresponding elements are similarly designated. The first of the two circuit loops connected across the source **1** of FIG. 2 comprises the diode **3**, the capacitor **2** and output system **4**, as in FIG. 1, although the order of the diode and capacitor is reversed. The second of the circuit loops connected across the source **1** in FIG. 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 FIGS. 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 FIG. 3, the circuit of which is similar to that of FIG. 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 FIG. 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 FIG. 3*b*, certain teachings of this invention may also be applied using diodes of a gaseous discharge type, indicated in FIG. 3*a* at **11**, in series with a relatively high resistance **12**. It will be obvious that a vacuum diode, indicated at **13** in FIG. 3*c*, 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 vs. 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 copending application Serial No. 40,232 filed July 1, 1960 by the same assignee, now Patent No. 3,176,060, entitled Gating System for Electrical Musical Instrument, in the name of Alfred J. Bissonette and one of the present inventors, Walter Munch, Jr. 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 **7***a*. 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 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, Serial No. 4,444, filed January 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 to 7. 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. 3*a*, 3*b* and 3*c* or the assemblies of diode elements and shunting impedances shown in FIG. 8 may be substituted. FIG. 8 is a diagram with noted values or parameters particularly appropriate to solid state diodes.

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 the copending application of John B. Brombaugh, entitled Keying Assembly for Electric Musical Instruments, Serial No. 134,201, filed August 28, 1961.

Considering in FIG. 5 the keying circuit for a source **1** for note C_3, components corresponding to those of FIG. 4 are similarly designated and connected. The output of diode **3***a* is connected to a collector **22**, also designated 8', 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 output (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 **15***a*, corresponding to the junction **15** of FIG. 4, is connected a resistor **10***a* for transmission of D.C. from the common source **7** to a point **15***b* in a keying circuit of similar character, comprising coupling capacitor **2***a* and diode **3***b* coupled, as shown to generator **1***a* of a continuous wave at a frequency corresponding to note C_2. 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, if desired, 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 **1***c* 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 **1***c* 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 **2***c* to a keying diode **3***c* of, for example, a solid state type. Gating voltage for the diode **3***c* may be furnished from a common source **7***c* via switch **9***c*; resistor **14***c* and resistor **10***c* as shown. Similarly, keying voltage may concurrently be supplied to diode **3***d* and **3***e* via resistors **10***d* and **10***e*, respectively, from resistor **14***c* which has been energized by switch **9***c* from the source **7***c*. Consequently signals from source **1***c*, previously mentioned, and from harmonically related continuous wave sources **1***d* and **1***e* as coupled into the named keying circuits by coupling capacitors **2***d* and **2***e*, 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**.

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 **9***c* 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 related 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.

As mentioned earlier in these specifications, square-wave sources of a "flip-flop" nature have become desirable particularly from a cost standpoint. (An example of a preferred form of square wave generator is shown in FIG. 10 and will be discussed hereinafter.) In FIG. 7, the bare essentials of a one note keying system for concurrent production of conventional organ tones and percussive type tones from a square wave source are illustrated. A source 1*f* of continuous square waves is shown coupled through coupling capacitor 2*f* to gating diode 3*f*, rendered conductive upon actuation by a playing key 52 of switch 9*f*, which supplies D.C. from source 7*f* via resistors 14*f* and 10*f*. As previously taught, a percussive tone may be derived in an output system 4*c* via a suitable filter 43, selected, as desired, by stop switch 44, the capacitor 16*f* providing the gradual decay. Tones of steady state type may be derived in the output system 4*c* by keying the square wave signal from the source 1*f* through a decoupling resistor 45, resistive key switch 46, decoupling resistor 47 and tone filter 48, as selected by stop switch 49. If it is desired that this be a "full" tone, with both even order and odd order harmonic components, additional signals may be combined via a path 50, supplying in a manner similar to that of the 8′ component, a 4′ component via decoupling resistor 45*a*, resistive switch 46*a* and level adjusting, decoupling resistor 51. In the interest of simplicity of drawings, further component circuits, such as might be desired for adding 2′ and 1′ signals at further reduced levels, are omitted, although it will be understood that it is within the scope of this invention that they be included. Also, via the path 50 to collector 52, a 4′ only tone of a square wave type, or of a type derivable therefrom by suitable filter means 53, known in the art, may be made available in the output system 4*c* by a stop switch 54. A decoupling resistor 55 may be required at the input of the filter 53.

It is within the scope of this invention that the FIG. 7 keying circuits for steady state tones be of the diode type as taught in connection with FIG. 5. Also, it will be understood that the diode 3*f* may be reversed in position if the D.C. source 7*f* is also reversed, if desired.

Regarding the operation of the diode circuit of FIG. 7, when the switch 9*f*, which may be operated in the conventional manner by a key 52 of a keyboard musical instrument, is in the open position, the continuously operating generator 1*f* applies a square wave to the left hand plate of capacitor 2*f* and a common return path. It will be obvious that during such excursion of the square wave as would tend to make the cathode 56 of the diode 3*f* positive, no current will pass through the diode 3*f*. During that portion of the excursion of the square wave which would tend to make the anode 57 of the diode 3*f* positive, a signal would be confronted with an open circuit with respect to direct current (the capacitor 2*f*, the switch 9*f* and capacitor 16*f* are all substantially an open circuit with respect to D.C.). Any current which flows through the diode 3*f* from right to left by virtue of leakage in the capacitors 2*f* and/or 16*f*, charges up these capacitors and raises the potential of the point 5*f* to a level sufficient to keep the diode 3*f* in a non-conducting state. Thus, in the condition indicated in FIG. 7, no signal other than a low level of "leak-through" will be present in the output system 4*c*. Herein lies the important "self-bias" teaching of this invention, which greatly simplifies and lowers the cost of the circuitry. It can be seen also that if the circuits of FIGS. 2, 3 or 4 contain unilaterally conductive diodes, such as solid state and vacuum types, the points 5 in these circuits will be carried to a level sufficient to bias the diodes off by virtue of charge built up on the coupling capacitor 2.

Returning to the operation of the circuit of FIG. 7, upon closure of the switch 9*f*, the capacitor 16*f* is charged to the level of the D.C. source 7*f* at a rate determined by the resistance 14*f* and the capacitor 16*f*. The D.C. level of the point 5*f* is thus below that of the anode 57 of the diode 3*f*, rendering it conductive and permitting passage of the negative excursion and at least a portion of the positive excursion of the square wave applied to the circuit by the generator 1*f*. So long as the key switch 9*f* is closed, signals from generator 1*f* will be present in the output system 4*c*. Upon opening switch 9*f*, the capacitor 16*f* will discharge through the resistor 10*f*, the diode 3*f* and output system 4*c* until such time as the diode 3*f* reaches its non-conductive state.

If the signal-to-leak-through ratio of the circuit of FIG. 7 is high enough to meet the needs of a give usage, this embodiment is the simplest form of our invention. However, if such diodes are employed that their capacitance would result in higher than tolerable leak-through, two or more diodes may be used in series. However, we prefer, in accordance with an important aspect of our invention to employ a bypass impedance between the junction of two diodes and a common return path, as illustrated in FIG. 8. This greatly improves the signal-to-leak-through ratio and enables the use of low cost diodes. In this figure also is illustrated means for concurrently deriving steady state organ tones in the output system.

Referring now to FIG. 8, the left hand portion of the circuit is similar to that of FIG. 7 and similar elements are correspondingly connected and numbered. However, to the anode 57 of diode 3*f* is shown connected a second diode 59 which may have similar characteristics to which is connected the output system 4*c*. Between the junction of the diodes 3*f* and 59 and a common return is connected an impedance, generally indicated at 60, of such value that it will be low with respect to the reverse impedance of the diodes 3*f* and 59 and high with respect to the forward impedance of diode 59. A preferred form of impedance 60 is illustrated as composed of a resistor 61 and a capacitor 62. The impedance of this combination is so chosen, because it is desired that in the non-conductive state, any signal from the source 1*f* which tends to leak through the diode 3*f* will find a ready path to a common return and will be negligible in the output system. In the conductive state of the diodes, the impedance of the path provided by the combination 60 will be of sufficient magnitude so as not to interfere with the operation of the circuit.

The diodes may be arranged in groups of eight each for a series of four percussive type circuits of the kind illustrated in FIG. 8, the collector 63 indicating the common output terminal of the four pairs of diodes. A collector 64 may direct the output of several keying groups to a percussive tone filter 43, stop switch 44 and output system 4*c*. Concurrent keying of a steady state tone may be accomplished by any of the keying systems hereinabove described, the one illustrated merely being exemplary. A decoupling resistor 65 is in series with a resistive switch 66, decoupling resistor 67, tone color filter 68 and stop switch 69 to the output system 4*c*.

Specific values of an exemplary circuit are indicated in FIG. 8, including those for a "short sustain" circuit as described in connection with FIG. 4. An alternative to such circuit is also illustrated in FIG. 8*a* which shows a circuit portion to replace the portion of FIG. 8 to the right of the dashed line 70. In this circuit, a solid state diode 71, for example, a commercially available silicon diode is shown in series with an appropriate resistor 72, single-pole, single-throw switch 73 and D.C. source 74.

Reference is now made to FIG. 9 for an explanation of the manner in which keying circuits of this invention can also be designed to act as wave shaping devices as well as for keying in systems having generators of square waves, although it will be realized that other type waves may be

modified by the circuits in accordance with known differentiating and clipping techniques, for example. The wave **75** is representative qualitatively of a signal applied, say in FIG. 7, by a generator **1***f* to the capacitor **2***f*. If the time constant of the combination comprising the capacitor **2***f* and the resistance offered to the signal from the point **5***f* through to the output system (with the diodes in the conductive state) is short with respect to one period of the square wave (represented by the distance between time t_1 and time t_2 on the chart of FIG. 9), the shape of the output current wave will appear qualitatively to be somewhat as indicated at **76**. The curved portion of the wave is seen to rise quickly and taper off in an exponential manner. If the time constant of the circuit is longer with respect to one period of the square wave **75**, the wave shape of the output current will be somewhat as indicated at **77**. With still further increase in the time constant of the circuit (readily changeable by increasing the capacitance of the coupling capacitor **2***f*), the output current wave approaches that of a square wave, as illustrated at **78** in FIG. 9.

Thus it will be seen that the object having to do with wave shaping by a keying circuit will have been achieved by this invention. It will be obvious to one skilled in the art that tone color circuits of conventional character for sawtooth waves may be employed to produce a wide variety of voices.

An exemplary square wave generator suitable for use in practicing the invention is illustrated in FIG. 10, wherein is shown one stage of a frequency divider chain for generating signals corresponding to a series of octavely related notes. The circuit is similar in certain respects to a tube multi-vibrator disclosed in U.S. Patent 2,418,521 to G. A. Morton et al., but is transistorized. Since the circuit components are given in FIG. 10 and since the operation will be familiar to one skilled in the art, detailed description and operation will not be discussed herein. The transistors T_1 and T_2 may be, for example, General Transistor Co. Type 2N–317. The lead **80** is the signal take-off point for the stage.

Referring now to FIG. 11, there is illustrated a complete percussive system for an electronic organ. It will be seen that the uppermost portion of the figure is a duplicate of the circuit of FIG. 8, the "Keying Circuit$_1$" portion enclosed by dashed lines corresponding to one section of the "Keying Assembly" of the aforementioned Brombaugh application. The keying circuit for steady state type tones, indicated generally at **81**, may be similar to that of FIG. 8 or, if desired, a keyed diode system, such as illustrated in FIG. 5 may be used. Or, if preferred, a keying circuit similar to that of FIG. 8, employing diode pairs, may be used without the gradual decay capacitor **16***f* and the "short sustain" circuit previously described. The blocks **82**, **83** and **84** represent additional keying circuits similar to "Keying Circuit$_1$," the dot-dash lines **85** indicating the boundary of those elements constituting one "Keying Assembly." The blocks **86–93**, representing keying assemblies designated with subscripts **2–9**, complete those constituting a percussive system in an exemplary instrument.

It can be seen that three keying assemblies, each with four keying ciruits, comprise the required components for one octave of notes. Blocks **91–93**, for example, would cover an octave. In accordance with previous partial teachings, the coupling capacitor **2***f* of the top note of a block **91** (assuming it to be lower in frequency than the top note of block **88**) would preferably be approximately twice the capacitance of the coupling capacitor for the top note of block **88**. This, for scaling purposes, assures a similar wave form in a square wave system for notes throughout a gamut.

By collecting from three representative groups of keying assemblies as at **94**, **95** and **96**, the outputs of these collectors may be brought to separate preliminary filtering circuits comprising, for the output lead **94**, a bypass capacitor **97**, a series capacitor **98** and a decoupling resistor **99**. A similar preliminary filter for the group collected at **95** comprises a capacitor **100** to a common return, a series capacitor **101** and a decoupling resistor **102**. Similar elements are present for the collector **96** at **103**, **104** and **105**. This separate collection of keying circuits provides for preliminary low pass filtering, so that a common low pass filter **106** of conventional character may be used for the whole gamut. As is conventional in the art, a switch **107** may be actuated by a stop tab (not shown) for transmittal of a percussive type tone, such as "vibraharp" to an output system **108**, which may be a conventional power amplifier and loudspeaker system. For percussive type wave forms of higher complexity, the adding network comprising resistors **109**, **110** and **111** connect the outputs from the collectors **94**, **95** and **96** and bring them through a lead **112** to a high pass filter comprising the shunt resistor **113** and series capacitor **114**, series resistor **115** and shunt resistor **116** to the output system **108** via stop switch **117**. An output of still higher complexity can be derived by way of a filter formed by shunt resistor **118** for series capacitor **119** of lower capacitance than that of capacitor **114**, to the output system **108** via stop switch **120**. These latter two voices may, for example, be designated as Organ Harp and String Percussion.

Thus that object having to do with percussive voices for a square wave generator system has been achieved.

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 source of alternating voltage representing musical tone, a load, a first circuit interconnecting said source and said load, said circuit including diode means and capacitive means connected in circuit with said diode means and said source, said diode means being connected to provide rectified charging current of one sign only to said capacitive means from said source, said capacitive means being connected completely and alone to back bias said diode means into non-conductive state with respect to said alternating voltage when charged from said source via said diode means, a further circuit comprising in series a source of direct voltage, a switch and a resistance, said further circuit being poled and connected to provide charging current to said capacitive means of sign opposite to said one sign and of magnitude sufficient to enable free passage of the entire wave form of said alternating voltage through said diode means to said load, said resistance having a value when taken in conjunction with the capacity of said capacitive means to provide a time constant selected to provide an audibly gradual transition of said diode means from the non-conductive to the conductive state on closure of said switch.

2. The combination according to claim **1** wherein said capacitive means is located directly between said source of alternating voltage and said diode means and in series with said source of alternating voltage and with said diode means simultaneously.

3. The combination according to claim **1** wherein said capacitive means is located directly between said diode means and said load and in series with both said diode means and said load.

4. The combination according to claim **1** wherein is further provided an auxiliary capacitor, means respon-

sive to closure of said switch for charging said auxiliary capacitor from said source of direct voltage, said auxiliary capacitor being connected in series with said capacitive means via said resistance.

5. In combination, a source of alternating tone voltage, a load, a first circuit interconnecting said source and said load, a common return path connected between said source and said load, said first circuit including rectifying diode means and capacitive means connected in series circuit, said capacitive means being charged by the rectified component of said alternating tone voltage to back bias said diode means into a non-conductive state and being the sole means in said first circuit for back biasing said diode, a further circuit shunting said capacitor means to said common return path, said further circuit including resistive means and a source of direct voltage, means for at will connecting said source of direct voltage to modify said charge on said capacitive means for forward biasing said diode means into a conductive state, said resistive means being connected in series with said source of direct voltage to provide, in conjunction with said capacitive means, a predetermined time constant selected to control the time rate of change of magnitude and polarity of said modified charge placed on said capacitive means by said direct voltage source to produce a relatively gradual musical sustain transition of said diode means from said non-conductive state to said conductive state, whereby selective control of the passage and envelope of said alternating voltage to said load is effected.

6. The combination according to claim 5 wherein said capacitive means is serially connected between said source of alternating voltage and said diode means.

7. The combination according to claim 5 wherein said capacitive means is serially connected between said diode means and said load.

8. The combination according to claim 5 wherein is provided further gradual decay capactive means connectible at will across said source of direct voltage to be charged thereby, and an additional discharge path for said further capacitive means operative upon disabling of said direct voltage source means to provide a discharge path for said gradual decay capacitive means.

9. The combination according to claim 5 wherein said diode means includes first and second rectifying devices, said rectifying devices being connected in series circuit and identically poled, impedance means connected between the junction of said first and second rectifying devices and said common return path, said impedance means having an impedance substantially greater than that of said diode means when the latter is in said conductive state, and having an impedance substantially less than that of said diode means when the latter is in said non-conductive state.

10. In an electronic musical instrument having a plurality of sources of alternating voltage producing tone signals corresponding to notes of the musical scale, and having an output system for converting tone signals to audible sound, the combination of means for selectively transmitting said tone signals from said sources to said output system, said transmission means comprising a plurality of circuit paths between respective ones of said sources and said output system, a common return path between said sources and said output system, keying means for selectively controlling the transmission of said tone signals through said circuit paths, and only one direct voltage source, each of said circuit paths comprising, in combination, a first circuit interconnecting one of said sources of alternating voltage producing tone signals to said output system, said first circuit including diode gate means and capacitive means connected in series circuit, said capacitive means being charged by said one of said sources of alternating voltage to back bias said diode gate means into a non-conductive state, a further circuit shunting said capacitive means to said common return path, said further circuit including resistive means and switch means, said switch means being selectively actuable in response to said keying means for connecting said direct voltage source in a conductive path in said further circuit to modify said charge on said capacitive means to forward bias said diode gate means into a fully conductive state, said resistive means being in series with said direct voltage source and cooperating with said capacitive means to provide a predetermined time constant to control the time rate of change of magnitude and polarity of said modified charge placed on said capacitive means by said direct voltage source to produce a relatively gradual transition of said diode gate means from said non-conductive state to said conductive state, whereby selective control of the envelope of said tone signal produced by said one of said sources of alternating voltage is effected, said diode gate means being a solid state diode gate means.

11. In an electronic musical instrument having a plurality of sources of alternating voltage for producing tone signals corresponding to notes of the musical scale and an electro-acoustic output system for converting tone signals applied thereto to audible sound, the combination of an organ tone channel, a sustain tone channel, means for interconnecting said channels between said plurality of sources and said output system, a common return path between said sources and said output system, a plurality of keying means, said keying means being associatively related one for one with said sources, said organ tone channel including a first plurality of circuit paths, a first plurality of key switches, each of said circuit paths including a separate one of said key switches, said key switches being selectively operable in response to selective actuation of said keying means to render said respective circuit paths conductive for enabling passage of said tone signals to said output system, said sustain channel including a second plurality of circuit paths, each of said second plurality of paths including a first circuit connected between one of said sources of alternating voltage and said output system, said first circuit including normally non-conductive unilaterally conductive gate means, a further circuit comprising in series a single source of direct voltage, switch means and resistive means, means connecting said further circuit intermediate the junction of said unilaterally conductive gate means and said capacitive means and said common return path, said direct voltage source being poled and connected to provide charging current to said capacitive means of sign selected to render said unilaterally conductive gate means conductive and of magnitude sufficient to enable free passage of alternating voltage from said one source thereof through said unilaterally conductive gate means to said output system, said switch means being selectively operable in response to selective actuation of said keying means to apply voltage from said single source of direct voltage to said capacitive means, said resistance means coacting with said capacitive means to provide a preselected time constant arranged to effect a relatively gradual transition of said unilaterally conductive gate means from the non-conductive to the conductive state.

12. The combination according to claim 11 wherein said capacitive means is serially connected between said one alternating voltage source and said unilaterally conductive gate means.

13. The combination according to claim 11 wherein said capacitive means is serially connected between said unilaterally conductive gate means and said output system.

14. The combination according to claim 11 wherein is provided further capacitive means selectively connected across said source of D.-C. voltage to be charged thereby, said further capacitive means cooperating with said resistance means to provide a preselected time constant for controllably modifying the speed of transition of said

unilaterally conductive gate means from said conductive to said non-conductive state.

15. In an electronic organ, a tone gating circuit comprising a source of alternating current tone signal, a first diode in series with said source, a second diode in series with said first diode, said first and second diodes being identically poled, a shunt path connecting between the junction of said diodes and a point of reference potential, a first capacitor in series with said diodes, a load connected in series with said diodes and said first capacitor, a source of gating voltage connected between (a) the junction of said first capacitor and one of said diodes and (b) said point of reference potential, said capacitor charging in response to said tone signal through said diodes to an off-bias voltage sufficient normally to cut off said diodes, said gating voltage having a magnitude and polarity adapted to overcome said off-bias voltage and to render said diodes fully conductive to said tone signal, a first resistance and a further capacitor connected in the recited order between said one of said diodes and said point of reference potential, a key switch and a second resistance connected in series between said source of gating voltage and the junction of said first resistance and said further capacitor, said resistances each having a value when taken with the capacitance of said further capacitor to provide relatively long time constants, compared with the period of said tone signal.

16. The combination according to claim 15 wherein is further provided means for at will modifying the rate of discharge of said further capacitor.

17. In an electronic organ, a tone gating circuit comprising a source of A.C. tone signal, diode means, a capacitor, a load, said source, said diode means, said capacitor and said load being all arranged in a series circuit, said capacitor being arranged to develop a D.C. off bias voltage for said diode means in response to said tone signal, a source of gating voltage, a key switch connecting said source of gating voltage to said diode means in on bias relation, said source of gating voltage having a voltage and polarity when applied to said diode means adapted to render said diode means fully conductive to said tone signal, and a tone forming circuit connected between said key switch and said diode means, said tone forming circuit including a first resistance and a further capacitor connected in the order named between said key switch and a point of reference potential, and a further resistance connected between said further capacitor and said diode means, said first resistance and further capacitor having a time constant on charge and said further resistance and further capacitor having a time constant on discharge adequate to gradually form the initial and terminal parts of said tone signal as passed by said diode means.

18. In an electronic organ, a tone generator, a solid state diode gate, a load, said tone generator, solid state diode gate and load being all connected in a series circuit in the order recited, means rendering said solid state diode gate normally non-conductive to the tone supplied by said tone generator, a source of direct keying voltage, a key switch connected between said solid state diode gate and said source, a two terminal storage capacitor connected to said source of direct keying voltage via said key switch such that said storage capacitor is charged on closure of said key switch, and a discharge impedance connected to said storage capacitor and having together with said storage capacitor a time constant sufficiently long to provide an audible sustain passage of said tone through said solid state diode on opening of said key switch, and a sustain switch for at will opening a circuit connecting one terminal of said storage capacitor to one terminal of said source of direct keying voltage, the other terminal of said storage capacitor being permanently connected to said solid state diode gate.

19. The combination according to claim 18 wherein is provided capacitive means connected to said solid state diode gate in series relation to said gate and said tone generator for normally maintaining said solid state diode gate in non-conductive condition solely in response to a rectified signal derived from the tone supplied by said tone generator.

20. In an electronic organ, a plurality of continuously running tone generators for producing organ tones, first paths extending from each of said tone generators and each including a solid state diode gate connected in cascade with said generator, and an electro-acoustic load circuit connected in cascade with all said gates, means normally maintaining said solid state diode gates all fully non-conductive, a single source of direct bias voltage, key switch means interposed between said source of direct bias voltage and said solid state diode gates, an operating key for each of said key switch means, the operating keys being operable to close said switches on depression of said keys, said keys being normally biased into undepressed state, the polarity and amplitude of said bias voltage being selected to selectively render said solid state diode gates fully conductive to the outputs of said tone generators on selective closures of said key switches responsive to depressions of said operating keys, further paths extending between each tone generator and said electro-acoustic load in parallel to and exclusive of said solid state diode gates, said further paths including a common tone filter, a separate storage capacitor connected in charging relation to said source of direct bias voltage via each of said key switch means, a long time constant discharge circuit means for said storage capacitors, one terminal of each of said storage capacitors being permanently connected to one of said solid state diode gates in such relation that its charge tends to maintain said solid state diode gate conductive, and said long time constant being sufficiently long to provide an audible tone sustain on opening of each key switch means by release of its key into depressed state.

21. In an electronic organ, a plurality of continuously running oscillators individually tuned to the frequencies of the musical scale, a single electro-acoustic load, means selectively connecting said oscillators to said load, said means comprising individual solid state diode gates each connected between a different one of said oscillators and said load, bias means normally maintaining all said gates in non-conductive condition, a single source of direct gating voltage, separate key switches for selectively and at will connecting said single source of direct gating voltage to said gates in such polarity as to render the selected gates conductive, a storage capacitor associated with each gate, a sustain switch for at will connecting each storage capacitor in a series circuit including a key switch and said single source of direct gating voltage, whereby when said single sustain switch is closed each storage capacitor is charged by said source of direct gating voltage on closure of the key switch included in its circuit, and a resistive discharge circuit for discharging each of said storage capacitors at audibly evident rate on opening of the key switch included in its circuit.

22. The combination according to claim 21 wherein is provided a separate bias capacitor connected to each of said gates, and means charging each of the bias capacitors in response to current deriving from one of said oscillators and in such sense as to bias the connected gate into its normal non-conductive condition, and wherein said direct gating voltage has a polarity selected to reverse the charges on the bias capacitors when said direct gating voltage is applied to said gates.

23. In a gating system, a tone oscillator having one terminal grounded and having a second terminal, a capacitor having a first terminal connected to said second terminal of said oscillator, said capacitor having a second terminal, an electronic valve having a first terminal connected to said second terminal of said capacitor, said electronic valve having a second terminal, an output system having a first terminal connected to said second terminal of said electronic valve and having a grounded sec-

ond terminal, and an exciting circuit connected between ground and said second terminal of said capacitor, said electronic valve being poled to generate a potential of first sign at said second terminal of said capacitor in response to output of said tone oscillator, and said exciting circuit including in series a switch and a voltage source poled to apply voltage of sign opposite to said first sign to said second terminal of said capacitor and of voltage greater than said potential of first sign at said second terminal of said capacitor.

24. The combination according to claim 23 wherein said exciting circuit further includes a relatively large resistance connected in series with said source of voltage, said capacitor and said relatively large resistance having a time constant sufficiently great to audibly gradualize rendering conductive of said electronic valve on closure of said switch.

25. The combination according to claim 24 wherein is further provided a gradual decay capacitor, resistive means connecting one terminal of said gradual decay capacitor to said second terminal of the first mentioned capacitor, and means grounding the other terminal of said gradual decay capacitor.

26. The combination according to claim 25 wherein is further provided means for at will accelerating decay of charge of said gradual decay capacitor.

27. In a gating system, a tone oscillator having one terminal grounded and having a second terminal, an electronic valve having one terminal connected to said second terminal of said oscillator and having a second terminal, a capacitor having one terminal connected to said second terminal of said valve and having a second terminal, an output system having one terminal connected to said second terminal of said capacitor and having a second grounded terminal, and an exciting circuit connected between said second terminal of said valve and another grounded terminal, said capacitor developing a charge of one polarity at said one terminal of said capacitor, said exciting circuit including in series a switch and a voltage source, said voltage source having a voltage terminal connected to said one terminal of said capacitor and being of polarity opposite to said one polarity, said voltage source having a voltage output greater than the voltage across said capacitor due to said charge.

28. The combination according to claim 27 wherein said exciting circuit further includes a relatively large resistance connected in series with said voltage source, said capacitor and said relatively large resistance having a time constant sufficiently great to audibly gradualize rendering conductive of said electronic valve on closure of said switch.

29. The combination according to claim 28 wherein said exciting circuit further includes a gradual decay capacitor, means responsive to closure of said switch for charging said gradual decay capacitor in response to said voltage source, said gradual decay capacitor being connected between ground and said one terminal of the first mentioned capacitor.

30. The combination according to claim 29 wherein is further provided means for at will accelerating discharge of said gradual decay capacitor.

31. A tone gating system comprising a closed loop comprising, in series and in the order recited, a tone generator, a capacitor, a diode gate and an output system, having a return connection to said tone generator, and an exciting circuit for controlling said diode gate, said exciting circuit extending between said return connection and the junction of said capacitor and said diode gate, said exciting circuit including a switch, a relatively large resistance and a voltage source, said voltage source having a polarity and magnitude selected to render said diode gate conductive for the total tone output of said tone generator, said resistance and capacitor having a time constant providing an audibly sensible rate of charge of said capacitor in response to said voltage source on closure of said switch.

32. The combination according to claim 31 wherein said return connection is a common ground.

33. A tone gating system comprising a closed loop comprising, in the order recited, a tone generator, a diode gate, a capacitor, an output system and a return path from said output system to said tone generator, and an exciting circuit for controlling said diode gate, said exciting circuit extending between said return path and the junction of said capacitor and said diode gate, said exciting circuit including a switch, a relatively large resistance and a voltage source, said voltage source having a polarity and magnitude selected to render said diode gate conductive for the total tone output of said tone generator, said resistance and capacitor having a time constant providing an audibly sensible rate of charge of said capacitor in response to said voltage source on closure of said switch.

34. The combination according to claim 33 wherein said return path is a common ground.

35. In a music system, a frequency divider stage constituting a tone generator, said frequency divider stage comprising a multivibrator, said multivibrator having a signal output terminal, a load, and a wave shaping circuit connected between said output terminal and said load, said circuit including in series a capacitor and a resistance having a time constant short relative to one half cycle of the output of said multivibrator.

36. The combination according to claim 35 wherein is further provided a diode gate in series with said wave shaping circuit and said tone generator, and means for at will and selectively rendering said diode gate conductive and non-conductive.

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