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 including of collectив 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 bringing 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 Riemstra 2,486,908 is in the second group. The third class is inclusive of Faulkner 2,811,069, Anderson et al. 2,811,887 and Anderson 2,833,310. 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 in 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 being 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 led to low cost frequency dividers of a "flip-flop" type, whose output is characterized by square waves. This development has made attractive the use of keying systems of the type disclosed in U.S. Patent 2,571,141 to Knaublaugh 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 from 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 this 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. 3a, 3b and 3c 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. Figure 7 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.

Figure 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.

Figure 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.

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

Figure 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.

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

Figure 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 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 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 Figure 2, wherein corresponding elements are similar designated. The first of the two circuit loops connected across the source 1 of Figure 2 comprises the diode 3, the capacitor 2 and 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 3, 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 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. 5,402,733 filed July 1, 1967, by the same assignee, now U.S. Patent 3,176,060, entitled "Harmonically Related Oscillation System for Electrical Musical Instrument, in the name of Alfred J. Bissone 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 Figure 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 Figure 1 may be preferable to that of Figure 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 Figure 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 Figure 4. In Figure 4, similar portions of the two circuits are similarly designated and connected. The resistor 13 in parallel 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 17a. 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, 21, depends on 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 19, capacitors 16 and 2—can be made in accordance with electrical design principles to achieve the desired onset of 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 diodes 15, 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, 1966 in the name of Walter Munck, Jr.

The terminal voltage of the D.C. source 21 is initially 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 to be included, if desired.

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 it 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. 3a, 3b and 3c or the assemblies of diode elements and shunting impedances shown in Fig. 8 may be substituted. Fig. 8 is a diagram with noted voltages 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 Electrical Musical Instruments, Serial No. 134,201, filed August 28, 1961.

Considering Fig. 5 the keying circuit for a source 1 for note C2, components 12 and 22 being connected, Fig. 4 are similarly designated and connected. The output of diode 3a 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 2,333,948. 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 15a, corresponding to the junction 15 of Fig. 4, is connected a resistor 19a 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 3a 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, 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 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 tendered via a 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 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 continuous 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.

If desired further, a conventional "percussive" tone, such as a "vibraphone," 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 keydown 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 9e 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 that capacitively 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
3,223,768

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 per-
cussive system thereof.

As mentioned earlier in these specifications, square-
wave sources of a "flip-flop" nature have become de-
sirable particularly from a cost standpoint. (An ex-
ample 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 percussive organ tones
and percussive type tones from a square wave source
are illustrated. A source 1f of continuous square waves
is shown coupled through coupling capacitor 2f to get-
ing diode 3f, rendered conductive upon actuation by a
playing key 52 of switch 9f, which supplies D.C. from
source 7f via resistors 14f and 10f. As previously
taught, a percussive tone may be derived in an output
system 4c via a suitable filter 43, selected, as desired,
by stop switch 44, the capacitor 16f providing the gradu-
ating decay. Tones of steady state type may be derived in
the output system 4c by varying the square wave signal
from the source 1f 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 and odd or
ordered harmonics of the same frequency, the signal
may be combined via a path 50, supplying in a manner similar
to that of the 8" component, a 4'th component via decou-
pling resistor 45a, resistive switch 46a and level adjust-
ing, decoupling resistor 51. In the interest of simplici-
ty 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 in-
cluded. Also, via the path 50 to collector 52, a 4'th only
tone of a square wave type, can be derived thereby
from a suitable filter means 53, known in the art, may be
made available in the output system 4c 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 3f may be reversed in posi-
tion if the D.C. source 7f is also reversed, if desired.

Regarding the operation of the diode circuit of FIG. 7,
which switch 9f, which may be operated in the con-
ventional manner by a key 52 of a keyboard musical in-
strument, is in the open position, the continuously op-
erating generator 1f applies a square wave to the left
hand plate of capacitor 2f 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 3f positive, no current will pass through the
diode 3f. During that portion of the excursion of the
square wave which would tend to make the anode 57 of the
diode 3f positive, a signal would be conducted
with an open circuit with respect to direct current (the
capacitor 2f, the switch 9f and capacitor 16f are all sub-
stantially an open circuit with respect to D.C.). Any
current which flows through the diode 3f from right to
left by virtue of leakage in the capacitors 2f and 16f,
charges up these capacitors and raises the potential of
the point 5f to a level sufficient to keep the diode 3f 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 4c. Herein lies the
importance of the "self-bias" teaching of the invention, which
greatly simplifies and lowers the cost of the circuit.
It can be seen also that if the circuits of FIGS. 2, 3 or 4
contain unilaterally conductive diodes, such as solid state
diode 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 9f, the capacitor 16f is
charged to the level of the D.C. source 7f at a rate de-
termined by the resistance 14f and the capacitor 16f.
The D.C. level of the point 5f is thus below the level of
the anode 57 of the diode 3f, 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 1f. So long as
the key switch 9f is closed, signals from generator 1f
will be present in the output system 4c. Upon opening
switch 9f, the capacitor 16f will discharge through the
resistor 10f, the diode 3f and output system 4c until
such time as the diode 3f 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 capaci-
tance 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 signals may be
curred 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 ele-
ments are correspondingly connected and numbered.
However, to the anode 57 of diode 3f is shown connected a second diode 59 which may have similar characteristics
to which is connected the output system 4c. Between
the junction of the diodes 3f and 59 and a common return
path 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 3f and 59 and high with
respect to the forward impedance of diode 59. A pre-
ferred 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
1f which tends to leak through the diode 3f will not find
a ready path to a common return and will be negligible in
the output system. In the conductive state of the diodes,
the impediment 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 4c. Concurrent keying of a steady state
tone may be accomplished by any of the keying systems
hereinafore 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 4c.

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. 8e 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 diode
is shown in his invention, which sharply increases the
cost of the circuit.

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. It is
shown in FIG. 9 that in this embodiment, wave-shaping
generators of square waves, although it will be realized that other wave types 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 if to the capacitor 2f. If the time constant of the combination comprising the capacitor 2f and the resistance offered to the signal from the point 5f 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 t4 and time t5 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 con-
stant of the circuit (readily changeable by increasing the capacitance of the coupling capacitor 2f), 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 octa-
tively 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 71 and 72 may be, for example, General Transistor Co. Type 2N2-317. The lead 80 is the signal take-off point for the stage.

Referring now to FIG. 11, there is illustrated a com-
plete 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,” 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 pre-
ferred, a keying circuit similar to that of FIG. 8, em-
ploying diode pairs, may be used without the gradual decay capacitor 16f and the “short sustain” circuit previously described. The blocks 82, 83 and 84 represent additional keying circuits similar to “Keying Circuit,” 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 embodiment.

It can be seen that three keying assemblies, each with four keying circuits, 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 2f 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 approxi-
mately twice the capacitance of the coupling capacitor for the top note of block 88. This, for scaling pur-
poses, assures a similar wave form in a square wave system for notes throughout a gamut.

By collecting those representative groups of key-
ing 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
95 capacitor 97, a series capacitor 98 and a decoupling re-
sistor 99. A similar preliminary filter for the group col-
lected at 95 comprises a capacitor 100 to a common
return, a series capacitor 101 and a decoupling resistor
102. Similar elementary assemblies for the output elec-
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 char-
acter may be used for the whole gamut. As is conven-
tional in the art, a switch 107 may be actuated by a step
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 capaci-
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 inter-

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-
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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 capacitive 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 audibly 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 the majority 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 associated with related one for one with said sources, said organ tone channel including a plurality of circuit paths, a plurality of key switches, each of said circuit paths including a plurality 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 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 being poled and connected to provide charging current to said capacitive means of signal 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 tone signal and 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 restore said diodes fully conductive to said tone signal, and a resistance and 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 constant 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 C.C. tone signal, a tone capacitor, a load, said source, said diode means, said capacitor and said load being all connected 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 said 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 and 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 gate when 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 said solid state diode gate fully non-conductive, a single source of direct bias voltage, a key switch means interposed between said source of direct bias voltage and said solid state diode gate, 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 each said electro-acoustic load in parallel to and exclusive of said solid state diode gates, said further paths including a common tone filter, a storage capacitor connected in series with said source of direct bias voltage via each said key switch means, a long time constant bias circuit means for said storage capacitors, one terminal of each 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 switch means 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 se-
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 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.

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 said diode gate, 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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