

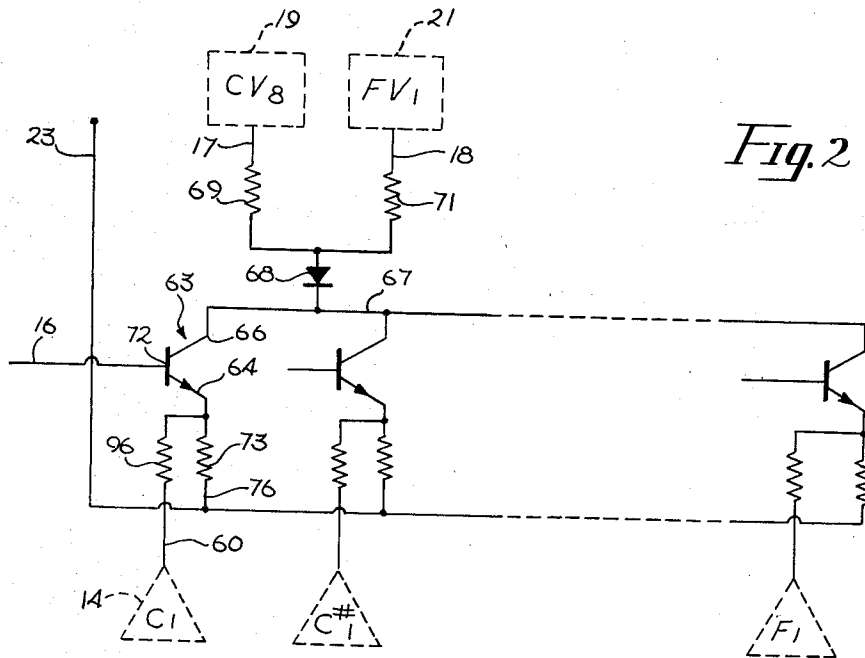
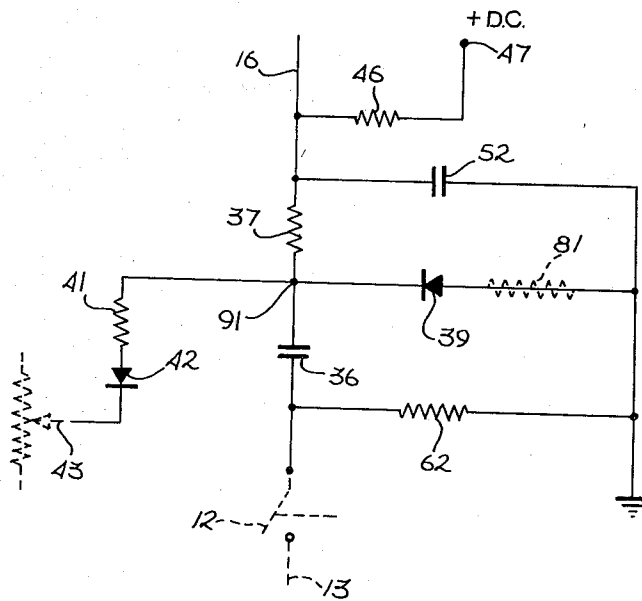
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ELECTRONIC MUSICAL INSTRUMENT DUAL PURPOSE
GATE AND KEYING CIRCUIT

3,543,281

Filed June 21, 1968

3 Sheets-Sheet 2



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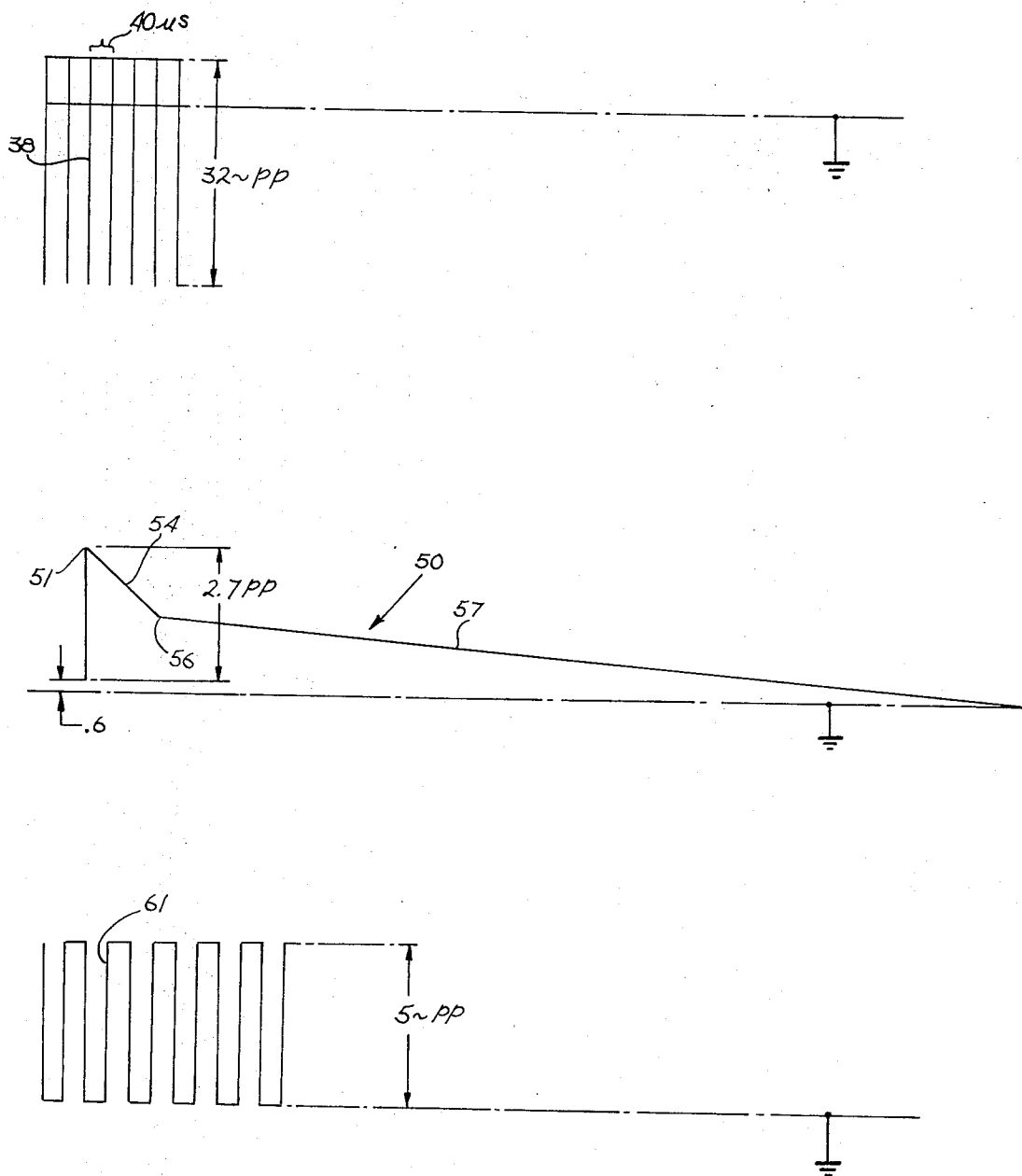


Fig. 4

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ELECTRONIC MUSICAL INSTRUMENT DUAL PURPOSE GATE AND KEYING CIRCUIT

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7 Claims

ABSTRACT OF THE DISCLOSURE

Three-element transistors are employed to gate tone signals from the tone sources to the output. An envelope signal is applied to the base of the transistor to allow it to pass tone signals applied from the emitter to the collector. Each base is connected to a keying circuit energized by a key switch with either AC or DC. When DC is employed, a pulse is developed through a series-connected capacitor, producing a percussed tone, such as from a string instrument. When AC is employed, it is rectified by a diode in series with the capacitor, and a sustain-type tone, such as an organ tone, is produced. A single keyer is connected to several footages of a given note. The footages may be selectively gated on or off or otherwise modulated by the bias applied to the emitters of the respective transistors.

BACKGROUND OF THE INVENTION

This invention relates primarily to an electronic keyboard musical instrument, although certain features will be seen to have application in other types of circuits. Modern technology in electronic organs is giving increasing variety to the types of tones which may be produced from a given instrument. In general an effort is made to simulate the tones of various other musical instruments. One of the characteristics of musical tones is the tone envelope, as determined by the manner in which the attack is performed and in which the decay or sustain is performed. Characteristically, certain instruments, such as plucked-string instruments, have a percussive type of envelope, that is, one in which the tone builds up and automatically decays in accordance with the characteristic of the instrument. To simulate such an instrument from an organ keyboard, it is necessary to provide that the depressing and holding down of a key will produce the plucked tone of the stringed instrument. Conversely, certain instruments, notably an organ, cause the sound to continue unabated as long as the key is held depressed.

In the past in general, it has been necessary to provide two separate keying circuits for each key of the organ, one to develop the percussive type of envelope, the other to develop the continued or sustain type of envelope. In the present invention, a single circuit develops both types of envelopes, depending only on the type of energizing voltage which is applied to the key switch.

Another problem attacked by the present invention is that of intermodulation from the output of the gating circuits. This has generally required in the past separate isolating circuits for each tone gate, in order to prevent unwanted tone signals from finding their way into the output system. In the present invention, isolating circuits in the form of diodes may be combined in groups of tone gates, thereby again minimizing component costs.

SUMMARY OF THE INVENTION

A keying circuit is provided for each key-operated switch. It consists, inter alia, of a series-connected capacitor and diode. Through the key switch, either high-frequency AC pulses or a steady DC may be applied to the capacitor, depending on the actuation of controls set by

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the organist. When DC is applied to the capacitor, a pulse is developed which is applied to an associated gate, causing a percussed tone to pass through the gate and to the output circuit. When AC is employed, it is rectified by the diode, thereby maintaining the capacitor charged, and producing a steady bias on the gate, rendering it continuously conductive to simulate an organ tone.

Each gate consists of a three-element transistor, with the envelope or keying signal being applied to the base, the tone signal to the emitter and the output taken from the collector. By controlling or adjusting the bias on the emitter, the output at the collector can be controlled. If the emitters of one footage of the gates are all connected together, this permits an individual footage to be separately controlled in a wide variety of ways, as for example, sustain length, complete cut-off, or tremolo modulation.

The individual transistors represent such a high impedance that intermodulation among tone signal sources is very small. As a result, the transistors may be grouped, with each group being provided with its own individual isolating diode.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the keying circuit of the present invention.

FIG. 2 is a circuit diagram illustrating a typical gate, shown in block form in FIG. 1.

FIG. 3 is a circuit diagram illustrating a typical keyer, shown in block form in FIG. 1.

FIG. 4 consists of three voltage wave forms, time related to illustrate roughly the timing relation among various voltages and signals in the circuits of FIGS. 1-3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, 11 represents a key in a typical keyboard instrument, such as an electronic organ. There is a full keyboard of such keys represented in this example by the range of C1 to B7 as shown. Each key 11 when depressed closes a normally open, single-pole switch 12, which applies voltage from a bus 13 to a keyer 3 corresponding to the key 11. The contents of the keyer 3 are illustrated in FIG. 3, which will be discussed hereinafter.

In FIG. 1, the organ is assumed, for example, to have three footage tabs, 8-foot, 4-foot and 2-foot, each of which has a horizontal row of gates 2 corresponding to that footage. The contents of each gate 2 are illustrated in FIG. 2, which will be discussed hereinafter. Each gate 2 consists of six sub-gates, comprised of three-element transistors. Each sub-gate accommodates and receives input from an individual source of tone signal illustrated at 14. Thus, referring, for example, to the 8-foot gates, the first gate accommodates the half octave from C1 to F1. The second gate accommodates the half octave from F#1 to B1, and so on up the scale to the highest note desired.

In the example illustrated, the keys have been shown up to B7 and the connections have been shown to all three footages. This, however, is simply to illustrate the general format, it being understood that in a conventional instrument, B7 would not appear at the 8-foot footage.

When switch 12 is closed, an envelope signal is applied to its output bus 16, which is connected to the corresponding sub-gate in each of the three footages. Appearance of an envelope signal on 16 enables the respective sub-gate or transistor to pass tone signal from the tone source 14 to the two outputs of the gate at 17 and 18. The output 17 is common to all the gates in a given footage, and is thence connected to a complex formant circuit 19. The output at 18 is connected to a flute formant circuit 21,

there being one such flute formant circuit for each of the gates 2.

The design of the gates 2, and specifically the individual transistor circuits therein, is such that by controlling the bias on the emitters of the transistors, a wide variety of control over the output signal appearing at 17 and 18 is achieved. Control of this bias is represented by the block 22, in which each of the three footages is connected to a respective common bus, exemplified by the bus 23 for the 8-foot footage.

Thus all of the 8-foot gates may be simultaneously controlled by the nature and magnitude of the bias on bus 23; that of the 4-foot gates by the bias on 24; and of the 2-foot gates by the bias on 26.

The character of the envelope signal appearing at the output 16 of the keyer 3, i.e., whether it be organ type or piano type (percussed), is determined by character of the energizing voltage applied to the keyer 3 by way of the key switch 12 from the bus 13. This in turn is determined by whether the double-throw switch 33 is in the left-hand position, where it is connected to a source of DC bias 31, or in the right-hand position, where it is connected to a source of AC bias 32. The AC bias 32 is a high-frequency pulse voltage, having a frequency for example, of 30 kilohertz, and a pulse or spike duration (negative going) of around five microseconds.

A keyer circuit 3 is shown in FIG. 3. As seen therein, the voltage residing on 13 is applied to a capacitor 36 by closing of the key switch 12. Assume that the switch 33 is set for organ keying, so that source 32 is connected to the bus 13. Capacitor 36 charges quickly through diode 39 by virtue of the rectification in the diode. The wave form that appears across the diode 39 is still essentially the power supply wave form shown at 38 in FIG. 4, but the negative-going peak is virtually at ground potential and the positive-going peak is at the peak-to-peak potential of 38, e.g., about 32 volts. A voltage division takes place in resistors 37 and 46, with capacitor 52 integrating the 30 kilohertz wave 38 down to the average DC level of the wave form. This DC level appearing at the output lead 16 turns the first transistor in gate 2 on, and it remains on as long as the key switch 12 remains closed.

When the key switch 12 is opened, the AC across 39 disappears. However, a charge equal to the DC average of the previous AC wave form remains. The charge on 36 then dissipates through resistors 37 and 46, provided slider 43 is at a voltage potential that is high enough to reverse bias diode 42. If the slider 43 is at ground potential, such dissipation is primarily through resistor 41 and diode 42, and is quite rapid. This gives the effect of normal organ keying.

With switch 33 in the left-hand position, the closing of key switch 12 will abruptly apply the corresponding DC potential from source 31 to the capacitor 36.

At the moment of closing of the key switch 12, virtually the full DC voltage from 31 appears at point 91 and is divided by resistors 37 and 46. The voltage on 16, shown at 50, thus rises abruptly to the point 51 shown in FIG. 4. Thereafter capacitor 36 charges relatively rapidly through essentially two parallel paths, one being the resistors 37 and 46, back to a small DC bias at 47 (e.g. .6 volt), the other being through resistor 41, diode 42 and back to the bias determined by the slider 43. The latter path has a considerably lower resistance than does the former. The aggregate charging current during the time that the diode 42 is conducting represents the fall in voltage shown at 54 in FIG. 4.

At 56 the potential on 16 has fallen to the point where the diode 42 is now reverse biased by the bias at 43. Conduction through 41 thereupon stops. Capacitor 36 continues to charge, however, through the alternate path 37/46 until the full charge of the source 31 has been attained. This continued charge is represented by the line 57 in FIG. 4. As readily seen in FIG. 4, the net result is an overshoot at 54, followed by a rather long tapering

off. This envelope thus simulates the striketone of a piano or the plucked sound of a harpsichord.

It is to be understood that the curve 50 in FIG. 4 is shaped only to show the relative timing between the keying source 38, the envelope signal 50, and the tone signal 61, which will be discussed hereinafter. Even here the timing is out of proportion, since the envelope 57 actually, and in fact, is long enough to embrace many thousands of cycles of tone 61; whereas, in FIG. 4 it is possible to show only a relatively few number of such cycles.

In a typical design, the capacitor 36 is completely charged in about 3.2 seconds, provided the key switch 12 remains closed for this length of time. When the key switch 12 is opened, even during a charging cycle, the capacitor 36 quickly discharges through resistor 62 and diode 39, which now becomes forward biased for the first time. This rapid discharge of 36 permits rapid reiteration of the key 11, if desired.

The effect of the envelope signal 50 appearing on the lead 16 will now be considered with reference to FIG. 2.

In FIG. 2, each gate 2 of FIG. 1 is shown consisting of a group of transistors 63. In the example shown there are six transistors per group. Each transistor 63 constitutes a gate means or sub-gate which serves to gate tone signals 61 applied from the tone signal source 14, through the emitter 64, to the collector 66 of the transistor 63. All collectors 66 of a given gate 2 are connected to a common bus 67 and thence through a single isolating diode 68 to the complex and flute voicing circuits 19 and 21, respectively, by way of resistors 69 and 71 respectively.

The envelope signal 50 is applied to the base 72 of the transistor 63 by way of the conductor 16. The emitter 64 is connected to the biasing bus 23 by way of a resistor 73.

When the organ is turned on, but not being played, tone signal of appropriate frequency appears constantly on each of the input conductors 60, this signal being represented by the curve 61 in FIG. 4. Since the bias on 72 is fixed at about 0.6 volt by source 47, and since the tone signal 61 goes in a positive direction only from the zero voltage or ground reference, the emitter 64 is normally reverse biased, and there is no passing of tone through the transistor 63. When an envelope signal appears at 16, whether a constant signal or a pulse signal, there is a corresponding passage of tone signal 61 through the transistor 63, which appears at the collector 66.

In the case of a steady voltage on 16, corresponding to an organ tone, the envelope signal at 72 is sufficient to turn the transistor 63 on, so that maximum passage of tone signal appears at collector 66. When piano-type keying is called for, by moving switch 33 to the left (FIG. 1), there is an envelope signal 50, which forms the envelope of the tone signal 61 appearing on the collector 66. During the period when there is a positive voltage (above 0.6 volt) on base 72, the transistor 63 becomes conductive during the negative or grounded half of the signal 61. During this half cycle, the transistor operates as a common-base amplifier, and produces a relatively large output at its collector 66.

During the time that the transistor 63 is conducting, any signal present on the collector 66 from another source, i.e., a companion transistor, is looking at the high collector impedance of a common-base amplifier. This results in minimum intermodulation distortion, such as is present in other types of gates, unless a great deal of signal output is wasted in isolating resistors. During the time that transistor 63 is not conducting, it appears much like a pair of back-to-back diodes with the center junction grounded. Capacitor 52 is the low impedance member that simulates the grounding of the center junction of the diodes.

As noted, typically, six transistors 63 are grouped together to form a gate 2, these being preferably six sequential notes of one footage. The output from these six transistors is applied via the bus 67 to the common diode

68. Thus, for every six notes of each footage, there is required only one diode 68, one resistor 69 and one resistor 71. There is thus added convenience and economy in structuring the circuit. Diode 68 represents an additional high impedance in series with the signal path when the gate is nonconductive. This permits the use of extremely brilliant voicing (many high-order harmonics), such as is required for harpsichord, without undesirable feed through or residual. The use of a diode 68 common to six notes is possible without unwanted intermodulation, because of the fact that the output impedance of the gates is high, i.e., a change in voltage on collector 66 caused from another subgate causes very little change in collector current.

The injection of the tone signal 61 through the emitter 64 permits a wide variation in signal control, by varying and controlling the bias on 64 through the bias of the lead 23. When 23 is grounded, operation proceeds in what may be called a normal fashion. That is, the tone signal 61 is passed to the collector 66 in substantially direct proportion to the envelope signal at 16, i.e., either the percussive signal 50 or the steady organ signal heretofore described.

If terminal 23 is biased to a positive potential equal to or exceeding the peak excursion 51 of the envelope 50, then each of those gates sub-gates 63 is completely blocked and no tone will appear at the output irrespective of what appears on 16. The individual bias points, i.e., points 76 (FIG. 2) may be bused or ganged in any way desired. In the embodiment shown, all of the points 76 associated with a given footage, e.g., the 8-foot footage, are bused together on the conductor 23. Thus, by biasing this conductor sufficiently high, the 8-foot footage can be completely cut off, while the other footages sound normally. Similar treatment may be selectively accorded to the 4- and 2-foot footages, through the biasing buses 24 and 26, respectively.

Alternatively, the biasing voltages on 23, 24 and 26 may have applied thereto tremolo voltages, since the magnitude of the tone signal at 66 varies inversely with the magnitude of the positive voltage applied to the point 76. Interesting effects simulating marimba, carousel and the like are achieved by switching the bias among the leads 23, 24 and 26 at a tremolo frequency. For example, an interesting carousel effect is achieved by placing a fixed bias on the 4-foot control lead 24, while applying a tremolo-frequency, symmetrical square wave of opposite phases to the respective leads 23 and 26. In this way the 8-foot footage is turned on when the 2-foot footage is turned off, and vice versa. This switching occurs at a tremolo-frequency rate, which, of course, may be controlled and varied.

Similarly, for organ tremolo, with the 4-foot gates at a fixed sounding bias, the 8- and 2-foot gates may be handled in a similar way, except that a sine wave is applied to the two leads 23 and 26, out of phase as in the case of carousel.

Circuit 22 may be some form of three-element ring circuit in which bias is applied around and around to leads 23, 24 and 26.

As has been explained, full bias, e.g., three volts, on control bus 23 will block sound completely from the output system. An intermediate bias will not only allow a diminished amplitude of signal to go through, but when energized by a percussive modulating signal at 16, will shorten the envelope time, i.e., the length of the tail 57, shown in FIG. 4. This is because an intermediate level at 23 will elevate the cut-off point for the wave 50 so that it is reached sooner than would be the case when 23 is grounded. Thus, each individual footage may have its envelope length (portion 57) individually controlled without altering the sustain length of other footages.

This capability of the circuit is employed to produce an effect known as "vibes," wherein an intermediate voltage, e.g., 2 volts, is set on bus 26 while the 8-foot bus 23

is turned fully "on," i.e., placed at ground potential. The intermediate voltage on 26 causes the envelope tail 57 to be shorter than normal for the 2-foot footage. This "vibes" effect is also enhanced by a very low-frequency tremolo applied to the entire output, i.e., after the tone signal has cleared the gate 2 onto the output buses 17 and 18.

As noted, the resistor 46 is returned to a small positive bias to offset the .6 volt threshold of the typical silicon transistor 63. This allows the envelope 50 to sustain out to a very low output signal before abruptly disappearing at the cut-off of the transistor.

If desired, the circuit may conveniently incorporate a means for attaining a very slow attack simulating an accordion. This is done by controlling the duty cycle of the high-frequency pulses 38 applied to the keyer 3.

This capability can best be understood by a discussion of the manner in which capacitor 36 charges under application of high-frequency voltage from 32. If the diode 39 were to be removed or reversed biased out of the circuit, the AC appearing at 91 would not have a DC component, because of the presence of capacitor 36. Assuming that capacitor 52 has virtually zero impedance at the 30 kilohertz of source 32, no control voltage, AC or DC, would appear on the conductor 16. With diode 39 in the circuit, and assuming perfect components, the first spike or pulse 38 would charge capacitors 36 fully.

Now assume that a resistor 81 is inserted in series with diode 39. Its value represents the aggregate total of all the resistances in the charging circuit for capacitor 36, and/or an actual resistor at 81. There is now created a tangible time constant for the charging of capacitor 36, which can be readily calculated. Assuming, by way of example, that the resistance represented by 81 is 10,000 ohms and that capacitor 36 is .2 microfarad, the normal time constant under DC energization would be 2 milliseconds. Assume further, for purposes of illustration, that the wave at 38 instead of being an asymmetric spike, as shown in FIG. 4, is a square wave, i.e., one having a 50-50 duty cycle, in which the negative polarity portion has the same duration as the positive polarity portion. The time required for the DC component to reach 63% of the final value is 4 milliseconds. The normal time constant of 10,000 ohms and .2 microfarad is 2 milliseconds; however, because of the fact that diode 36 is conducting only one-half of the time, i.e., on the negative half cycle of the square wave, the time required to reach the same charge is twice as long. Thus, as far as the time constant is concerned, the 10,000-ohm resistance performs as though it were 20,000 ohms.

In similar vein, a 1,000-ohm resistor at 81 would respond as if it were 50,000 ohms, when the duty cycle of the wave 38 is 20/80, i.e. 80% on the positive side and 20% on the negative side.

Since the attack of the envelope signal appearing at 16 is controlled by the charging rate of capacitor 36, and since this in turn is determined by the effective or apparent time constant of the charging circuit, it will be readily seen that the attack characteristics can be directly controlled by controlling or adjusting the duty cycle of the pulse wave 38 shown in FIG. 4. This may be done either by lowering the frequency, i.e., the pulse repetition rate, or by changing the percentage of time of a given cycle shared between the positive and the negative portion of the cycle.

As noted hereinbefore, the point 56 (FIG. 4) at which the envelope spike terminates and the tail or sustain 57 begins is determined by the point at which diode 42 stops conducting. This in turn is determined by the bias set by the slider 43. The highest positive bias, e.g., 18 volts, would effect piano simulation. A voltage of about plus 16 volts would simulate harpsichord, while 12 volts would simulate a banjo.

As noted, slider 43 would be moved all the way to ground for normal organ keying. This latter, of course, would be associated only with energization from the

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source 32. If slider 43 is placed at a positive potential equal to or greater than the residual charge potential left on capacitor 36 at the instant of key switch opening, no current will flow through resistor 41 and diode 42. This gives the effect of organ sustain. Placing slider 43 at an intermediate bias potential gives the "sustain reverb" effect.

Summarizing, voltage parameters which have been found quite successful in an actual circuit are as follows:

AC keying source 32: 32 volts peak to peak, 40 microseconds positive, 5 microseconds negative

DC keying source 31: 36 volts

Bias at 98: plus 8 volts

The above power supplies produce substantially corresponding values at the juncture 91 (FIG. 3). That is, the peak voltage 51 (FIG. 4) appearing at the point 91 is about 36 volts peak to peak.

The envelope signal 50 appearing at conductor 16 has a peak voltage at 51 of about 2.7 volts. Under AC keying the voltage at 16 is about 2.2 volts DC.

As noted, the duration of the percussion envelope 50 is in the order of 3.2 seconds for typical piano operation.

The bias at 46 is typically around plus 20 volts DC.

The peak-to-peak voltage of the tone signal derived from a tone source 14 is typically about five volts.

A satisfactory circuit has been constructed and operated having the following parameters:

In FIG. 2: resistor 69, 10,000 ohms; resistor 71, 47,000 ohms; resistor 73, 33,000 ohms; resistor 96, 47,000 ohms.

In FIG. 3: resistor 41, 220,000 ohms; resistor 46, 390,000 ohms; capacitor 52, .01 microfarad; capacitor 36, .22 microfarad; resistor 62, 39,000 ohms; resistor 37, 4.7 megohms.

In FIG. 1: resistor 97, 820 ohms.

Whereas the present invention has been shown and described herein in what is conceived to be the best mode contemplated, it is recognized that departures may be made therefrom within the scope of the invention which is, therefore, not to be limited to the details disclosed herein, but is to be afforded the full scope of the invention as hereinafter claimed.

What is claimed is:

1. Keying circuit for musical instrument comprising: gate means for modulating passage of tone signals, tone means for applying tone signals to the input of said gate means, output means for receiving tone signals from the output of said gate means, key means for enabling passage of tone signal through said gate means in accordance with modulating signals applied to said gate means by said key means, key-operated switch means for applying energy to said key means for forming said modulating signals, a first source of electric energy, a second source of electric energy of significantly different character than said first source, means for selectively connecting said first or second source to said switch means, thereby to apply the corresponding energy to said key means, said key means including means for discriminating between energy of said sources to produce significantly different envelope signals corresponding to said sources.

2. Keying circuit for musical instrument comprising: a plurality of first footage gates, a plurality of second footage gates, each said plurality of gates being fed by tone sources, a plurality of key means corresponding to musical tones for applying envelope signals to said gates, and a corresponding plurality of key-operated switches for energizing the respective key means, a first source of electric energy, a second source of electric energy of significantly different character than said first source,

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means for selectively connecting said first or second source to said switches, thereby to apply the corresponding energy to said key means,

said key means including means for discriminating between energy of said sources to produce significantly different envelope signals corresponding to said sources.

3. Keying circuit in accordance with claim 2, wherein: said first source comprises a direct voltage, said second source comprises voltage pulses, said key means includes a capacitor and diode connected in series to rectify said pulses.

4. Keying circuit in accordance with claim 3, including:

means for adjusting the duty cycle of said pulses, thereby to adjust the attack of said envelope signal.

5. Keying circuit for a musical instrument comprising: a plurality of tone signal sources, an output system,

a plurality of gate means for gating tone signals to said system,

a plurality of keys for enabling corresponding gates,

a plurality of gate means output buses, each connected to receive the tone signal output from a given group of gate means,

a plurality of diodes, corresponding to said buses, and connected to respective buses to pass tone signal output from said buses to said system.

6. Gate circuit for musical instrument, comprising:

a plurality of tone signal sources,

a first plurality of gates corresponding to a first footage,

a second plurality of gates corresponding to a second footage,

each said gate comprising a transistor having collector, emitter, and base,

a plurality of keyers corresponding to said tone signal sources, and effective to develop an envelope signal in response to depression of a key corresponding to a given tone signal,

circuit means for applying said envelope signal to the bases of those transistors in each footage which correspond to each given tone signal,

circuit means for applying a given tone signal to a corresponding transistor emitter,

circuit means for applying a bias to the emitters of the transistors constituting said first footage gates,

circuit means for applying a bias to the emitters of the transistors constituting said second footage gates, whereby each said footage may be separately controlled by control of the bias on said emitters.

7. Variable attack keying circuit comprising:

a source of energizing pulses,

a capacitor,

a charging circuit including a rectifier for charging said capacitor from said source,

means for applying the voltage on said capacitor to a tone signal gate,

means for varying the duty cycle of said pulses,

whereby the apparent charge rate of said capacitor is varied, thereby varying the attack of the voltage applied to said gate.

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WARREN E. RAY, Primary Examiner

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