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3,499,093

CHIME SYSTEMS AND THE LIKE FOR ELECTRONIC ORGANS

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2 Sheets-Sheet 1

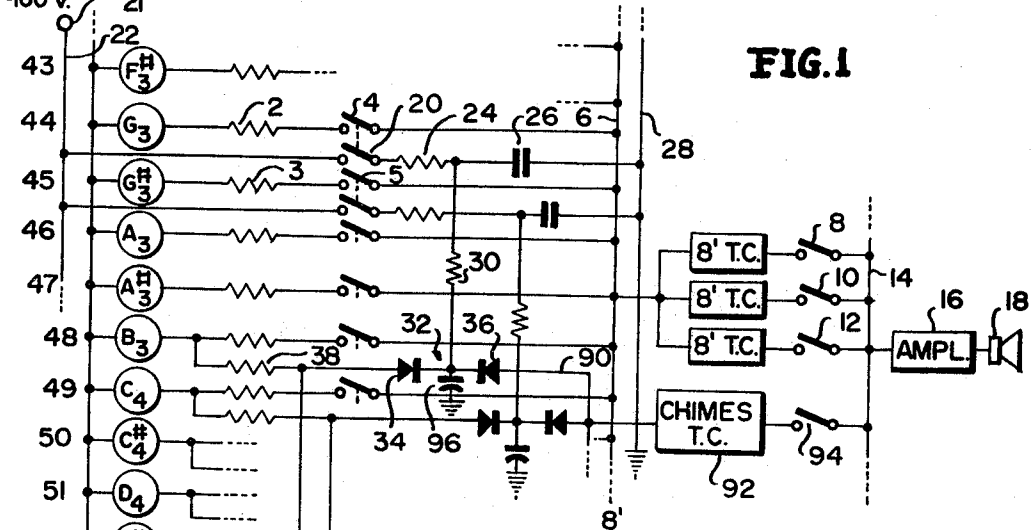


FIG. 1

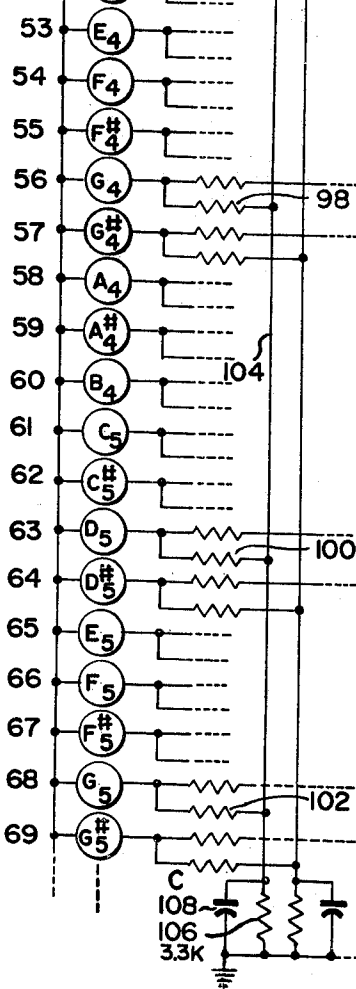


FIG. 5

NOTE	M3	8TH	12TH	15TH
G ₃	48	56	63	68
G ₃ [#]	49	57	64	69
A ₃	50	58	65	70
A ₃ [#]	51	59	66	71
B ₃	52	60	67	72
C ₄	53	61	68	73
C ₄ [#]	54	62	69	74
D ₄	55	63	70	75
D ₄ [#]	56	64	71	76
E ₄	57	65	72	77
F ₄	58	66	73	78
F ₄ [#]	59	67	74	79
G ₄	60	68	75	80
G ₄ [#]	61	69	76	81
A ₄	62	70	77	82
A ₄ [#]	63	71	78	83
B ₄	64	72	79	84
C ₅	65	73	80	85

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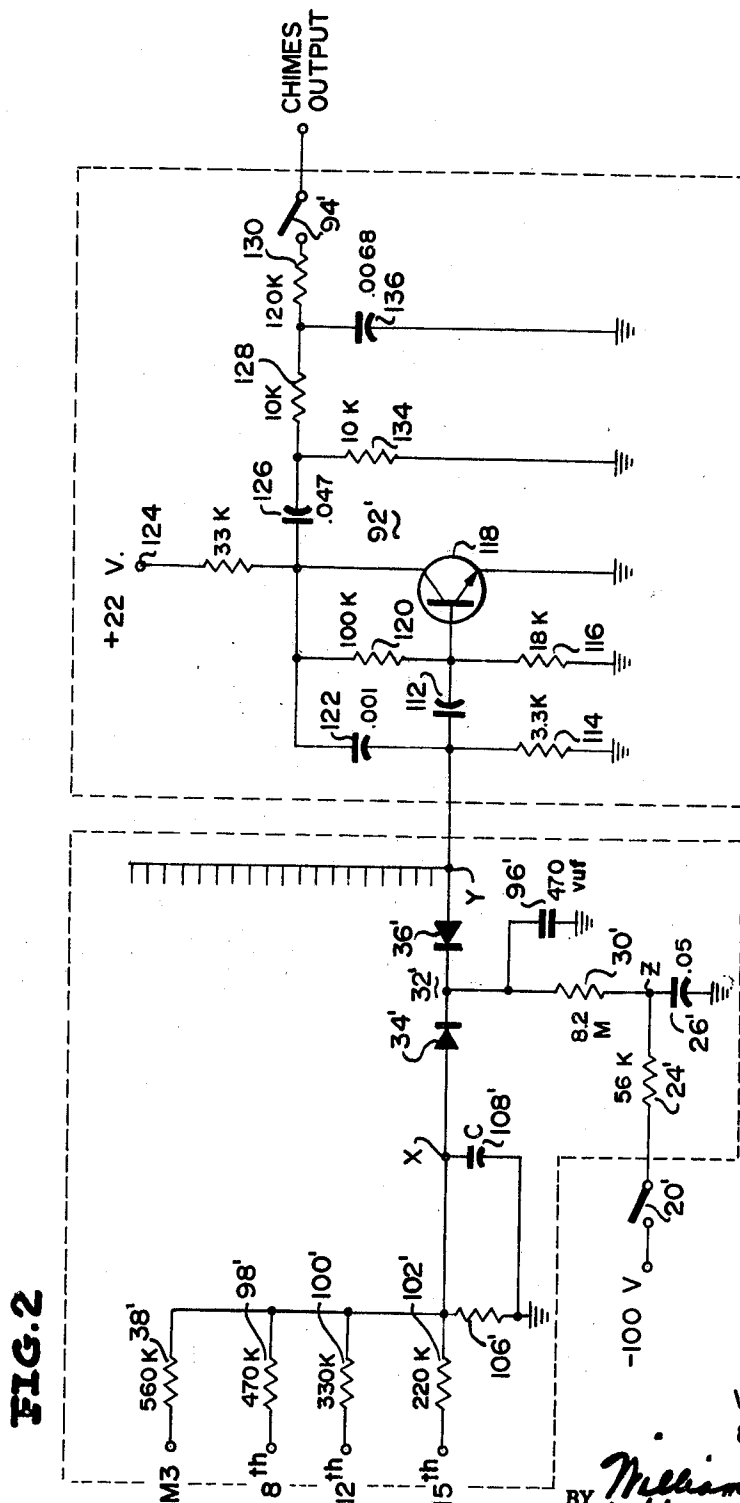


FIG. 2

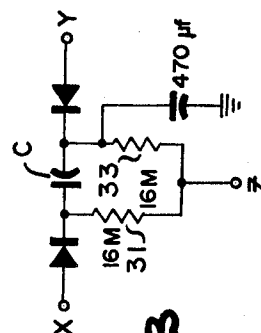


FIG. 3

NOTES	C (in μf)
G3-C4	.05
C ₄ ^H -F ₄ ^H	.03
G4-C5	.02

FIG 4

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CHIME SYSTEMS AND THE LIKE FOR ELECTRONIC ORGANS

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17 Claims

ABSTRACT OF THE DISCLOSURE

Tone sources corresponding with chime tone components are connected via current weighting resistances in parallel with one another, and all in series with a common diode gate. The latter consists of back-to-back diodes arranged to provide a linear response, thereby to avoid even-order harmonics or first order heterodyne products. The diodes are separated by a capacitor and supplied with bias current separately from a common source via large resistances, to maintain bias current to the diodes equal and small.

This invention pertains to electronic organs, and, in particular, relates to the production of chime-type tones and the like in such instruments by means of a single gate for each tone, and to gates suitable for such production.

It is desirable in electronic organs, including those for institutional use, to provide circuits for the simulation of tones corresponding to chimes, carillons and similar instruments. Furthermore, it is well known that tones of such instrument may be simulated by concurrently keying or gating from a plurality of sources a plurality of tone-signal components corresponding to the partials of such tones. An example of such a system is disclosed in a co-pending application, Ser. No. 443,354, filed Mar. 29, 1965, (now Patent No. 3,417,189, issued Dec. 17, 1968) in the name of Frank J. Kramer, Jr., and assigned to the assignee of the present application. Such systems have been technically complex in that a plurality of key switches or tone-signal gates have been required for the respective tone partials.

Briefly describing a preferred embodiment of the invention, chime tone components, such as tone sources corresponding with M3, 8th, 12th and 15th, are connected via current weighting resistances in parallel with each other, and all in series with one diode gate. The diode gate consists of two series diodes having corresponding electrodes connected together, and bias current is supplied to the corresponding electrodes to vary the resistance thereof. By matching the diodes and the resistance of the circuitry completing a DC path for each diode, and DC current to both diodes remains equal. In such case the diode pair has an approximately linear symmetrical response to small signals, and therefore does not generate even-order harmonics or first-order heterodyne products.

In a modification of the preferred embodiment of the invention, the corresponding electrodes of the diode gate, which in the preferred embodiment were directly connected together, are separated by a capacitor and supplied with bias current from a common source but via separate large but equal resistances. Thereby, the necessary condition is maintained that bias currents to the two diodes are equal.

The present invention has for a primary object the provision of a chime-type system requiring only one key switch and one gate for each tone having a plurality of tone-signal components.

A further object is the provision of a simple and low

cost system for producing tones of a multiple-partial character, from multiple tone sources.

Another object of the invention resides in the provision of a novel diode gate capable of passing the output of plural tone sources without generating harmonic or heterodyne products.

Still another object of the invention is the provision of a linear gate for A-C signals consisting of series diodes having corresponding electrodes connected together, and having a source of bias current connected to the corresponding electrodes.

Another object of the invention resides in the provision of a linear gate for A-C signals consisting of series diodes having corresponding electrodes connected together via a capacitor, the common electrodes being connected to a common source of bias current through equal resistances, so that equal DC currents flow to the diodes from the bias source.

A more specific object of the invention resides in the provision of a chime-type tone generating system, in an electric organ, wherein tone signals from a plurality of tone sources, scaled to proper relative amplitudes, are applied concurrently to a single gate for transfer in response to a gating current, the gate being of such character that even-order harmonics or first order heterodyne products are not generated thereby.

These and other objects which will be set forth hereinafter, or will be apparent to those skilled in the art upon reading this specification, are accomplished by those systems and circuits of which will now be described exemplary embodiments, reference being made to the accompanying drawings, wherein:

FIGURE 1 is a partially-schematic, partially-block diagram of an exemplary chime system according to this invention;

FIGURE 2 is a schematic diagram of the circuit details for producing one note in the system of FIGURE 1;

FIGURE 3 is a schematic diagram of an alternative to the gate portion of FIGURE 2;

FIGURE 4 is a chart showing values of a scaling capacitor for different ranges of tones in the gamut; and

FIGURE 5 is a chart showing which tone-signal sources in a system such as that of FIGURE 1 are used for the required components of various chime-type tones.

A plurality of tone-signals corresponding to the component partials of a chime-type tone cannot be fed to a single, ordinary, abrupt-attack, gradual decay gate to simulate such a tone, because non-linearities in the gating element would result in sum and difference frequencies of the added signals as well as in other intermodulation distortion. Kramer, in the aforementioned application, disclosed a multiple-gate, multiple-filter system such that component tone-signals are not combined until after the processing by individual gates (one for each signal) and by eight-note filters. Though the Kramer system is highly satisfactory, it is relatively expensive in that a gate is required for every component of every tone. Also, the filtering needs are believed to be excessive.

According to the present invention, the chime-tone-signal components are fed at low level to series-opposed-diode gates comprising matched diodes and associated components, so that bias currents to both diodes are equal. By scaling the input signals to compensate for filter roll-off, a single output filter may suffice for all tones in the gamut.

Referring to FIGURE 1, a series of tone-signal sources labeled F_3 , G_3 , G_3 . . . represent continuously-running generators such as stages of frequency-dividing flip-flop circuits, known in the art. These sources are also numbered 43, 44, 45 . . . indicating their relative position in a complete gamut for an organ system. From the

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source G_3 , signal may be passed through a decoupling resistor 2 and a key switch 4 to supply steady-state organ tone signal to a collector 6 for conventional 8' tones as modified by appropriate tone-color filters 8', T.C., selectable by tone-color switches 8, 10, 12 for passage via collector 14 to amplifier 16 and electroacoustic transducer 18, which may be a loudspeaker system. Preferably, the key switch 4 is of the "gradual-contact" type, such as that disclosed in U.S. Patent 3,206,701 to Gregory, so that key clicks are avoided.

Similarly, signal from the source G_3 may be passed through a decoupling resistor 3 and key switch 5 to collector 6 and on to the filter and output systems, and so on, for all tones.

The system thus far described is a conventional one for producing standard organ tones. However, according to the present invention, a key switch 20 may be ganged, or otherwise concurrently-operated with conventional key switch 4, for connecting a direct current terminal 21 via a bus 22 and a resistor 24 to a capacitor 26 connected to a common return path 28 to ground. Also, via resistor 24 and via another resistor 30, the direct current is transmitted to a tone-signal gate 32 composed of two back-to-back diodes 34 and 36 in series with a further resistor 38 between a source B_3 and a collector 90, to which is connected a chimes tone-color filter 92 in series with a chimes stop-switch 94, to the output system comprised of collector 14, amplifier 16 and loudspeaker 18. The gate 32 also includes a by-pass capacitor 96. Also connected to the input of the gate 32 are sources G_4 , D_5 and G_5 via isolating resistors 98, 100 and 102, respectively. The common input lead 104 has also connected thereto a resistor 106 and capacitor (c) 108 in parallel.

Similar circuitry is shown connected to sources G_3 and C_4 , so that the facilities for two adjacent semi-tones are illustrated. However, in the interests of simplicity of the drawings, further gates and associated connections are omitted therefrom.

In operation, when the G_3 key (not shown) for actuation of the ganged switches 4 and 20 is operated, these switches are closed. Thus conventional organ signal becomes available, via switch 4, on the collector 6 for tone-coloration, as desired, by closure of stop switches 8, 10 and/or 12, in the tone-color filters 8' T.C., which may, for example, be Diapason, Flute and Horn, respectively. Depending upon which switch 8, 10 or 12 is closed, corresponding tone signals will be amplified in the amplifier 16 and converted to sound in the electroacoustic system 18. If no conventional tone is desired, switches 8, 10, 12 may be left open. Upon closure of the chime stop switch 94, however, the direct current keyed by switch 20 opens the gate 32 by causing conduction of the diodes 34, 36, allowing signal from the source B_3 to pass through via the bus 90, to be modified by the chimes filter 92 and to pass via collector 14 to the amplifier 16 and electroacoustic device 18 for conversion to sound. At the same time, however, signal from the sources G_4 , D_5 and G_5 also passes through the gate 32 for modification by the filter 92 and conversion to sound in system 18. One skilled in the art will realize that the sources B_3 , G_4 , D_5 and G_5 provide the major third, eighth, twelfth and fifteenth partials of a chime tone corresponding to a fundamental G_3 , which itself is not provided as such but is heard as a resultant based on the presence of the other components.

The rate at which these signals build up is determined principally by the time constant of the combination of resistors 24 and 30 and capacitor 26. The relative amplitudes of the tone-signals from B_3 , G_4 , D_5 and G_5 is determined in part by the resistors 38, 98, 100 and 102, respectively. As the G_3 key (not shown), which operates switches 4 and 20, is released, these switches open and the signals passing through the gate 32 decay at a rate determined principally by the time constant of the capacitor 26 and resistor 30. Capacitor 96 is for reducing feed-through when the gate 32 is inoperative. The reactance of

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capacitor 96 should be low with respect to the non-conductive impedance of gate 32, but high with respect to the latter's conductive impedance.

FIGURE 2 illustrates a one-note version of the system of FIGURE 1 with components correspondingly numbered, but with prime marks and labeled with values, together with the details of a chime-tone filter circuit 92'. The latter comprises input capacitor 112, with resistors 114 and 116 connected from either side of capacitor 112 to ground, as shown. The latter resistor is also connected to the base of transistor 118, whose emitter is grounded and whose collector is connected back to the base by a resistor 120, with a capacitor 122 connected as shown to the input side of capacitor 112. The collector is fed from a source (not shown) of positive voltage at terminal 124. The output circuit of the transistor 118 comprises the series combination of a capacitor 126, resistor 128, resistor 130 and stop-switch 94', a resistor 134 and a capacitor 136 being connected to ground as shown.

In operation, the capacitive feedback provided for the transistor amplifier by the capacitor 122 provides a roll-off at high frequencies, while the R-C stage comprising the resistors 128 and 130 and capacitor 136 provides a low-pass characteristic for additional high-frequency roll-off in the filter circuit 92'. Use of a single filter for a complete chime-type tone is an important feature of the invention, and is feasible because the tone components are scaled by capacitor 108' and resistances 38', 98', 100', 102', to compensate for filter response roll-off. In other words, the higher-frequency components, which would otherwise come through at a lower level than the lower-frequency components, are intentionally attenuated less than the lower-frequency components. As a matter of fact, the components are attenuated by groups of about six notes such that they come through at about the same loudness level to ear. Thus, instead of the roll-off characteristic being approximated by the sloping lines of the filter characteristic which determine the levels of the components in the groups, gently sloping sawtooths are described by joining the adjacent ends of the lines corresponding to the scaled levels of the component tones. Typical values of attenuation for Major third, eighth, twelfth and fifteenth partials are down 26, 24, 21 and 18 db, respectively, not including filter attenuation.

With regard to the gate 32' of FIGURE 2 (and its counterpart in FIGURE 1), the diodes 34' and 36' must be matched as to characteristics, so that the direct current flowing through resistor 30' will divide equally between them. Clearly, tone components will remain equal in the two diodes.

The diodes 34', 36' in series, cathode to cathode, are inherently non-conductive when unbiased. On application to both cathodes of a negative bias current, the diodes become conductive, but their DC and AC resistances remain respectively equal, if the diodes are matched. The AC resistance of the diode-pair can then be shown to be practically linear, and to decrease as a function of increase of bias voltage. To achieve such linearity, it is requisite that DC bias current through both diodes be and remain equal. AC resistance is measured as slope of a static or DC characteristic, and the effect of operating the diodes with two diverse slopes, i.e., with two distinct biases, is the same effect as is achieved by a non-linear circuit, i.e., generation of heterodyne products.

If the current is not divided equally, the total series impedance will increase. In the extreme case where one diode has no current through it, it will be essentially an open circuit, thus decreasing the available signal. Secondly, as the current in one diode decreases, the ratio of AC to DC current increases with a resulting increase in distortion. It is well known that an approximately linear symmetrical impedance has no even-order harmonic or first-order sum-and difference frequency distortion. Matching the diode currents in the above manner

permits the gate to be operated at a sufficiently high signal level which is not interfered with by DC transients or other noise sources.

An alternative to gate 32' which obviates the necessity of matching diodes, is illustrated in FIGURE 3, wherein the network between points X, Y, Z may replace the gate 32' at X, Y and Z of FIGURE 2. The capacitor C of FIGURE 3 does not allow passage of DC current and therefore forces equal currents from resistors 31 and 33 to flow through the input and output diodes, respectively. Thus, both diodes are biased to the same impedance level.

The chart of FIGURE 4 gives typical values for capacitor C in FIGURES 1, 2 and 3.

Reference is now made to FIGURE 5, wherein the chart sets forth the relationship between tone-signal sources and the note produced by their combination according to the circuitry illustrated in part. For example, the chime tone G₃ requires a major third from source 49, an eighth from source 57, a twelfth from source 64 and a fifteenth from source 69.

Frequency conversion systems employing back to back diodes are well known. Such frequency conversion systems must, in order to accomplish conversion, operate at relatively high levels, whereas the gate of the present system operates at low levels. The response of a non-linear system may be denoted (1) $i=ae+be^2+ce^3 \dots$ where i is current and e is voltage and a , b and c are parameters.

In the present system, if the diodes are matched and if their associated resistances are matched, $b=0$, and for small signal level of operation

$$\frac{ce^3}{ae} = \frac{ce^2}{a} \ll 1$$

In a sense, the purpose of the back-to-back diode gate of the present invention is to vary values of a , b , c in the above Equation 1 over a wide range of values, from a variable DC source, while maintaining

$$\frac{be}{a}, \frac{ce^2}{a}, \frac{de^3}{a}, \text{ etc.}$$

of negligible value compared to unity. Under these conditions, gating without significant conversion products is possible.

We claim:

1. In an electronic musical instrument, the combination comprising:
 - a plurality of continuously-running tone-signal sources corresponding to a gamut of musical tones suitable for providing a chime sound,
 - a single direct-current-actuable, abrupt-attack, gradual-decay gate coupled to a predetermined plurality of said tone-signal sources on a predetermined-tone-partial basis, said gate being arranged and adapted to pass signals derived from said sources concurrently but substantially without intermodulation distortion when subjected to said direct current,
 - a source of said direct current,
 - keying means coupling said source of direct current to said gate,
 - an output system coupled to said gate, wherein said gate comprises:
 - a pair of back-to-back diodes in series between said tone-signal sources and said output system,
 - a decay capacitor coupled between a common return path and the junction between said diodes, and wherein said direct-current keying means comprises:
 - a switch and a resistor in series between said direct-current source and said junction between said diodes, and
 - including a plurality of amplitude leveling impedance means, respectively coupled between the input of said gate and separate ones of said tone-signal sources, and
 - a summing resistor and a bypass capacitor coupled in

parallel between a common return path and the input to said gate.

2. The combination according to claim 1, including tone color means coupled between said gate and said output system, and
- amplifier means coupled between said gate and said tone-color means.
3. An electronic organ comprising in combination:
 - a plurality of continuously-running tone-signal sources corresponding to a gamut of musical tones,
 - a plurality of steady-state key switches coupled respectively to said tone-signal sources,
 - collecting means coupled to said steady-state key switches,
 - steady-state tone-color circuits coupled to said collecting means,
 - an electroacoustic output system coupled to said steady-state tone-color circuits,
 - a plurality of chime-tone gates each coupled respectively to at least some of said tone-signal sources on a chime-tone-component bases,
 - a direct current source,
 - a plurality of chime key switches operated respectively concurrently with at least some of said steady-state key switches and coupled respectively between said chime-tone gates and said direct-current source, and
 - a chime-tone-color circuit coupled between said chime-tone gates and said output system.
4. The combination according to claim 3, including:
 - a plurality of groups of chime-component-level impedances coupled respectively between groups of said tone-signal sources and said chime-tone gates on a chime-component basis, and
 - a plurality of parallel combinations of individual resistors and individual capacitors coupled respectively between a common return path and the inputs of said chime tone gates.
5. The combination according to claim 3, wherein said chime-tone gates comprise each:
 - a pair of back-to-back diodes coupled between a tone-signal source and said chime-tone-color circuit, and
 - a decay capacitor coupled between a common-return path and the junction between said diodes, and wherein:
 - a plurality of attack resistors are respectively connected between said chime key switches and the junction between said diodes.
6. The combination according to claim 5, including amplifier means coupled between said chime-tone gates and said chime-tone-color circuit.
7. In an electronic organ having a plurality of tone-signal sources corresponding to a gamut of musical tones and an output system, the combination comprising:
 - a plurality of direct-current-actuable, abrupt-attack, gradual-decay gates, each of said gates having connections to those of said tone-signal sources corresponding to a major third, an eighth, a twelfth and a fifteenth partial of a chime tone,
 - a direct-current source,
 - a plurality of switch means connected between said direct-current source and said gates, and
 - tone-color means coupled between said gates and said output system.
8. The combination according to claim 7, said tone-color means including:
 - amplifier means connected to said gates, said amplifier means having a capacitive feedback path between the input and output thereof, and
 - low-pass filter means coupled between said amplifier means and said output system.
9. The combination according to claim 7, wherein said gates comprise each:
 - a pair of back-to-back diodes coupled between said sources and said tone-color means,
 - a decay capacitor coupled between a common return

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path and the junction between said diodes, and wherein there is connected between said switches and said gates respectively

a pair of resistors in series, and

a capacitor connected between said common return path and the junction between said resistors.

10. The combination according to claim 8, wherein said amplifier means comprises

a transistor having a collector, an emitter and a base, said base being coupled to one of said gates, said feedback path being connected between said collector and said gate, said emitter being connected to said common return, and said low-pass filter being coupled between said collector and said output system.

11. In an electrical musical instrument

a plurality of tone sources suitable for generating a chime tone when sounded concurrently,

a single gate,

said plurality of tone sources being connected in parallel with each other and all concurrently and permanently in series with said single gate,

said single gate including a first diode and a second diode,

means connecting said diodes in a series circuit,

a load for said gate,

an electrode of said first diode being connected in a DC circuit to said load,

an electrode of said second diode being connected in a DC circuit to said source, said electrodes being of corresponding types, and

means including a single DC bias current source for applying equal bias currents to said diodes in such sense as to render said diodes conductive with always equal DC bias currents of such value that intermodulation of signal from said plurality of tone sources is substantially absent in said load.

12. The combination according to claim 11, wherein the remaining electrodes of said diodes are directly connected together through a path of essentially zero AC impedance.

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13. The combination according to claim 11 wherein the remaining electrodes of said diodes are connected together through a capacitor, and wherein said last recited means includes separate equal multi-megohm resistances extending from said current source to said remaining electrodes, respectively.

14. The combination according to claim 11 wherein said tone sources are square wave sources.

15. The combination according to claim 11 wherein said tone sources include a major third, and 8th, and 12th and a fifteenth partials of a chime tone corresponding with a given fundamental tone.

16. The combination according to claim 11 wherein is provided a capacitor connected from at least one of the remaining electrodes to a point of reference potential, said capacitor having a value low relative to an open circuit condition of said gate and high relative to a highly conductive condition of said gate.

17. The combination according to claim 11 wherein said means for applying equal bias currents to said diodes includes a timing capacitor, a normally open key switch, means for charging said timing capacitor from said current source in response to closure of said key switch, and a relative high discharge timing resistance connected in series between said timing capacitor and said diodes, whereby on opening said key switch said timing capacitor supplies said bias current to said diodes via said timing resistance.

References Cited

UNITED STATES PATENTS

3,336,432	8/1967	Hurvitz	84—1.24	X
3,391,240	7/1968	Utrecht	84—1.26	X
3,407,260	10/1968	Schrecongost	84—1.26	X

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