United States Patent

[11] **3,580,980**

[72] Inventor **Dale M. Uetrecht**
Cincinnati, Ohio

[21] Appl. No. **755,043**
[22] Filed **Aug. 26, 1968**
[45] Patented **May 25, 1971**

[73] Assignee **D. H. Baldwin Company**
Cincinnati, Ohio

[54] **DIODE KEYING SYSTEM FOR ELECTRONIC ORGAN**
32 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **84/1.22,** 84/1.24, 84/1.26
[51] **Int. Cl.** **G10h 1/06**
[50] **Field of Search** 84/1.01, 1.24, 1.26, 1.22

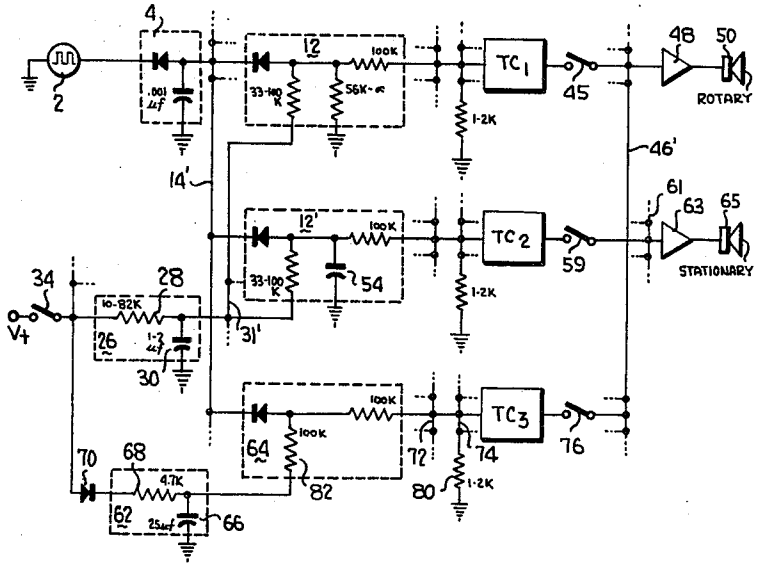
[56] **References Cited**

UNITED STATES PATENTS

3,223,768	12/1965	Munch, Jr. et al.	84/1.01
3,389,211	6/1968	Slaats	84/1.26X
3,391,240	7/1968	Uetrecht	84/1.26X
3,408,449	10/1968	Tinker	84/1.26X
3,417,189	12/1968	Kramer, Jr.	84/1.01

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—W. H. Breunig

ABSTRACT: The keying networks between continuously running square wave tone signal sources and the sound output system of an electronic organ each consist of an isolating diode gate for each source, followed by the parallel combination of at least two keying diode gates of simplified circuitry which either gate-through the square wave signal without change in wave shape (for odd-order-harmonic tones) or gate-through and modify the wave-shape into sawtooths (for full harmonic tones). A keyed activating circuit for the isolating diode gate and the keying diode gates corresponding to a selected key may contain a single key switch connected to a source of direct current and a common R–C attack network for two adjacent footage keying diode gates as well as for the paralleled keying diode gates. A common coupler switch for coupling between keyboards is located between the direct current source and auxiliary key switches ganged respectively to the main key switches for a given manual, the auxiliary key switches being connected to a diode to isolate them from the main key switches in the coupled keyboard.



5 Sheets-Sheet 1

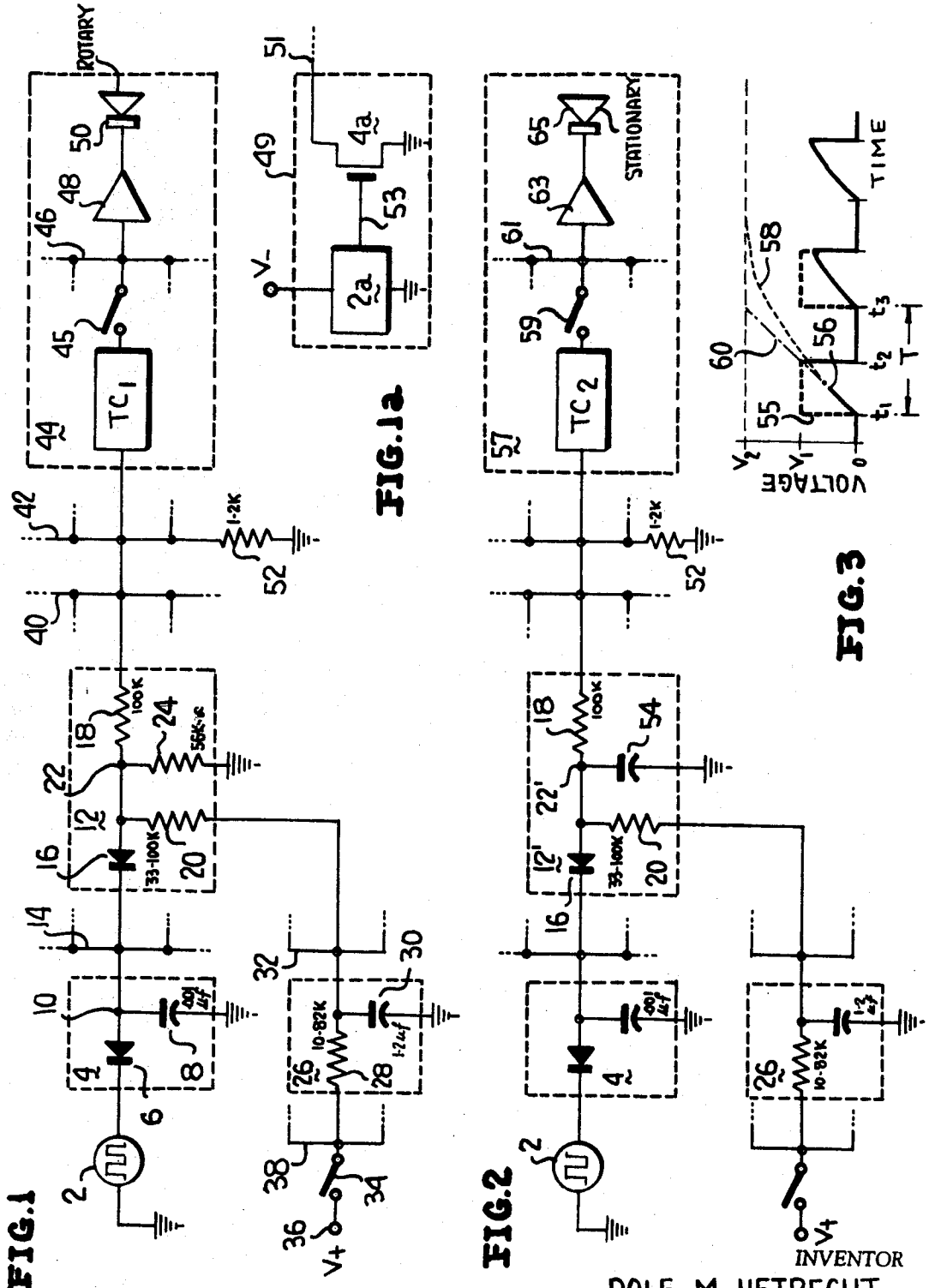


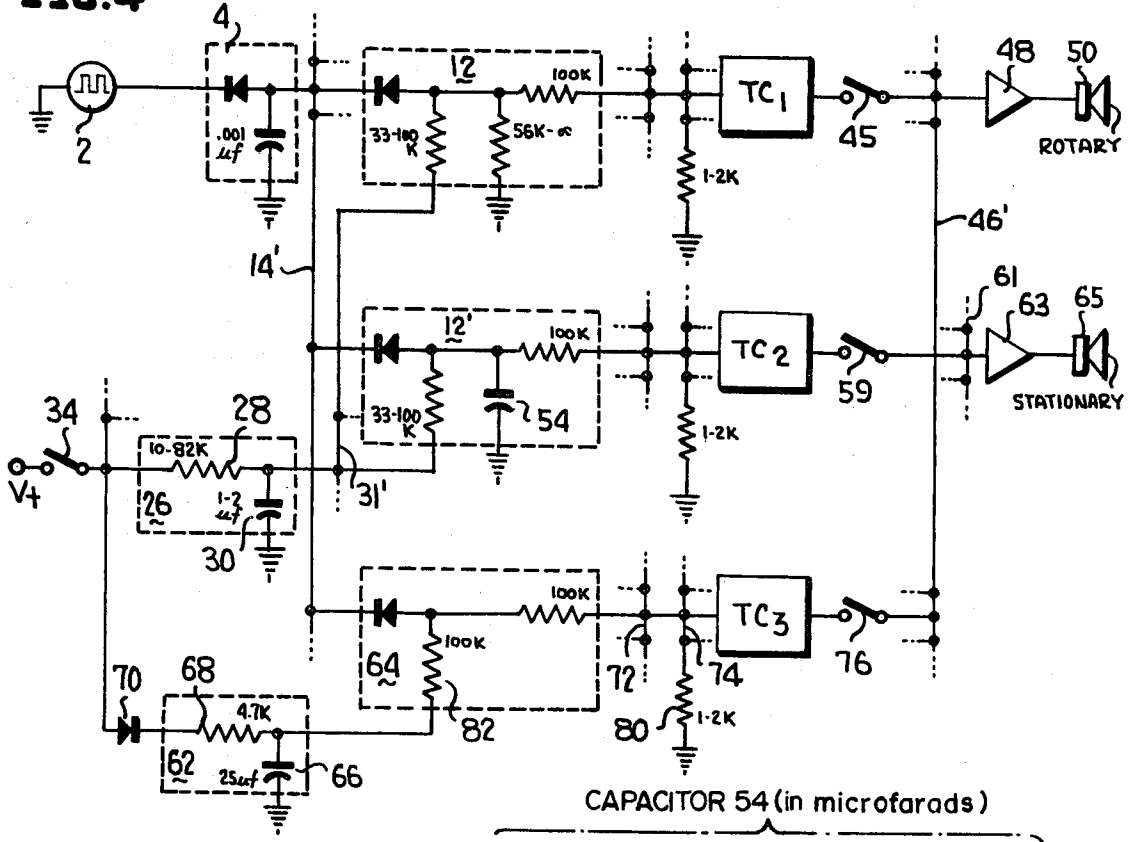
FIG.1

FIG.1a

FIG.2

FIG.3

FIG.4



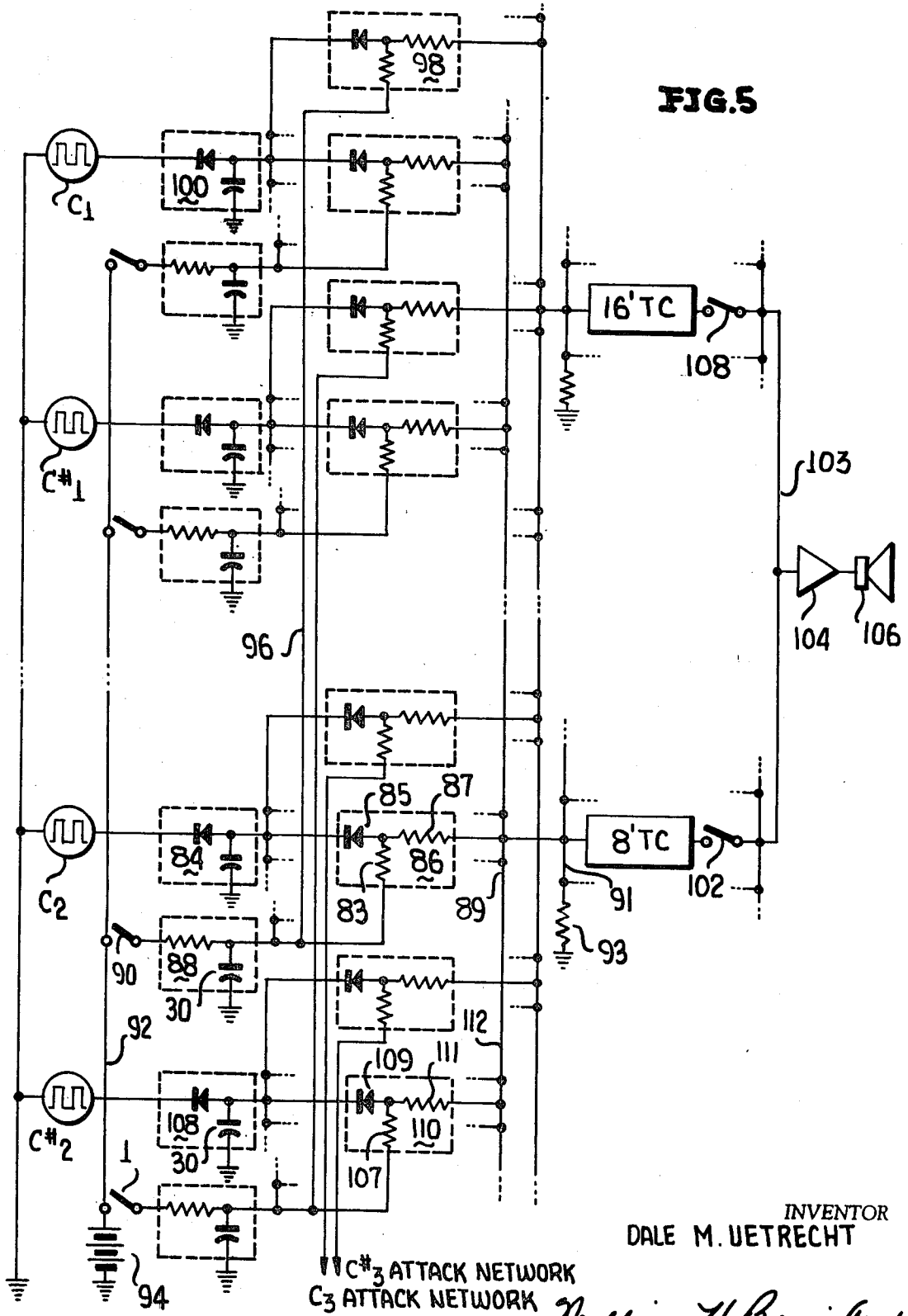
CAPACITOR 54 (in microfarads)

	R_g (ohms)	R_s (ohms)	C, C#, D	D#, E, F	F#, G, G#	A, A#, B
1st. OCTAVE	100 K	—	0.12	0.10	0.10	.082
2nd. OCTAVE	82 K	—	.082	.068	.068	.056
3rd. OCTAVE	68 K	330 K	.056	.047	.047	.039
4th. OCTAVE	56 K	180 K	.039	.033	.027	.022
5th. OCTAVE	47 K	120 K	.022	.018	.018	.015
6th. OCTAVE	39 K	82 K	.015	.012	.010	.0082
7th. OCTAVE	33 K	56 K	.0082	.0068	.0056	.0047
8th. OCTAVE	33 K	56 K	—	—	—	—

FIG.7

INVENTOR
DALE M. UETRECHT
BY William H. Brewer, Agent

FIG.5



INVENTOR
DALE M. UETRECHT

BY William H. Brenner, Agent

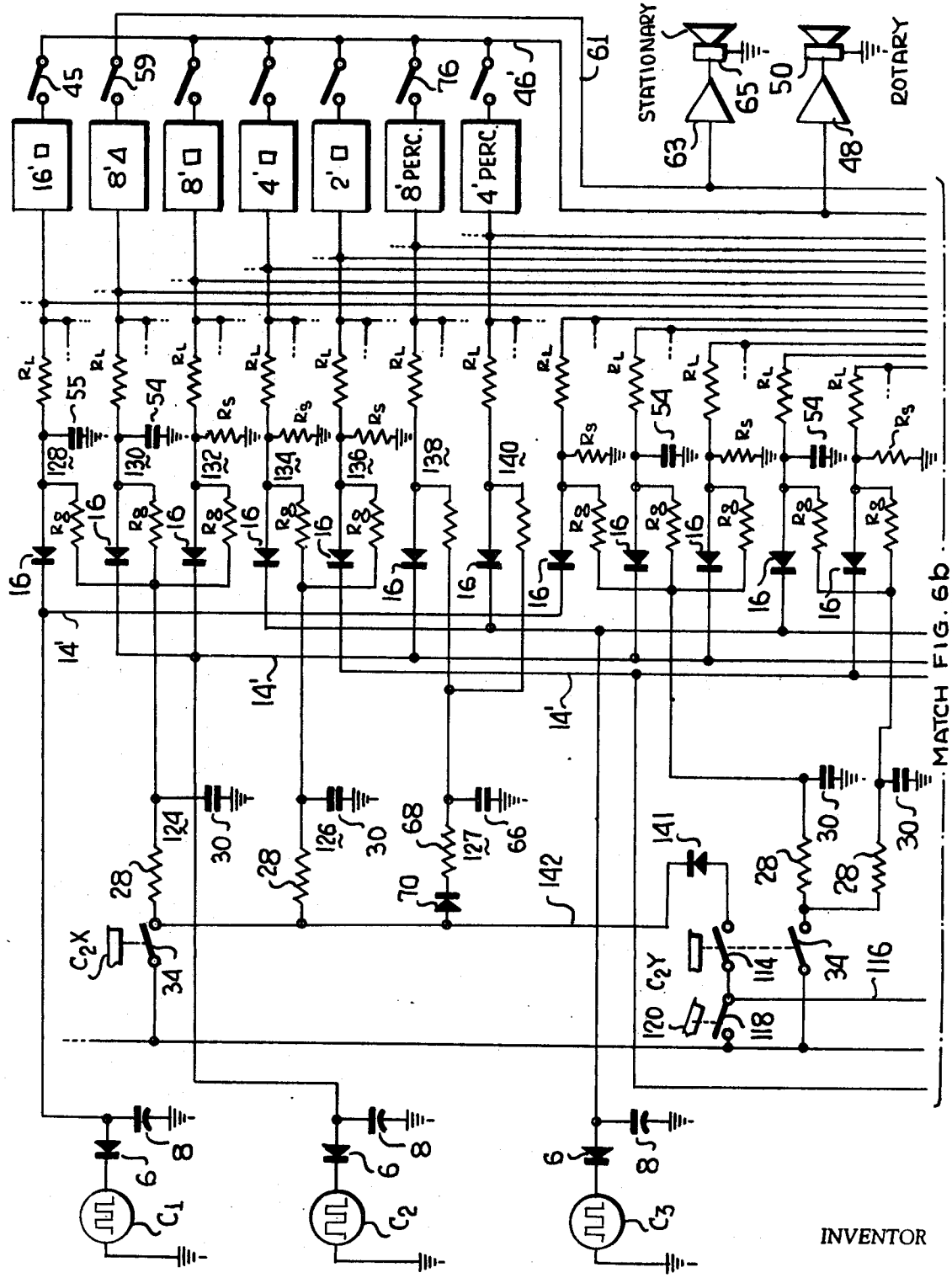

16'
8'4
8'
4'
2'
8'PERC.
4'PERC.
STATIONARY
ROTARY
MATCH FIG. 6b
INVENTOR
DALE M. UETRECHT
BY William W. Brenny, Agent

FIG. 6a

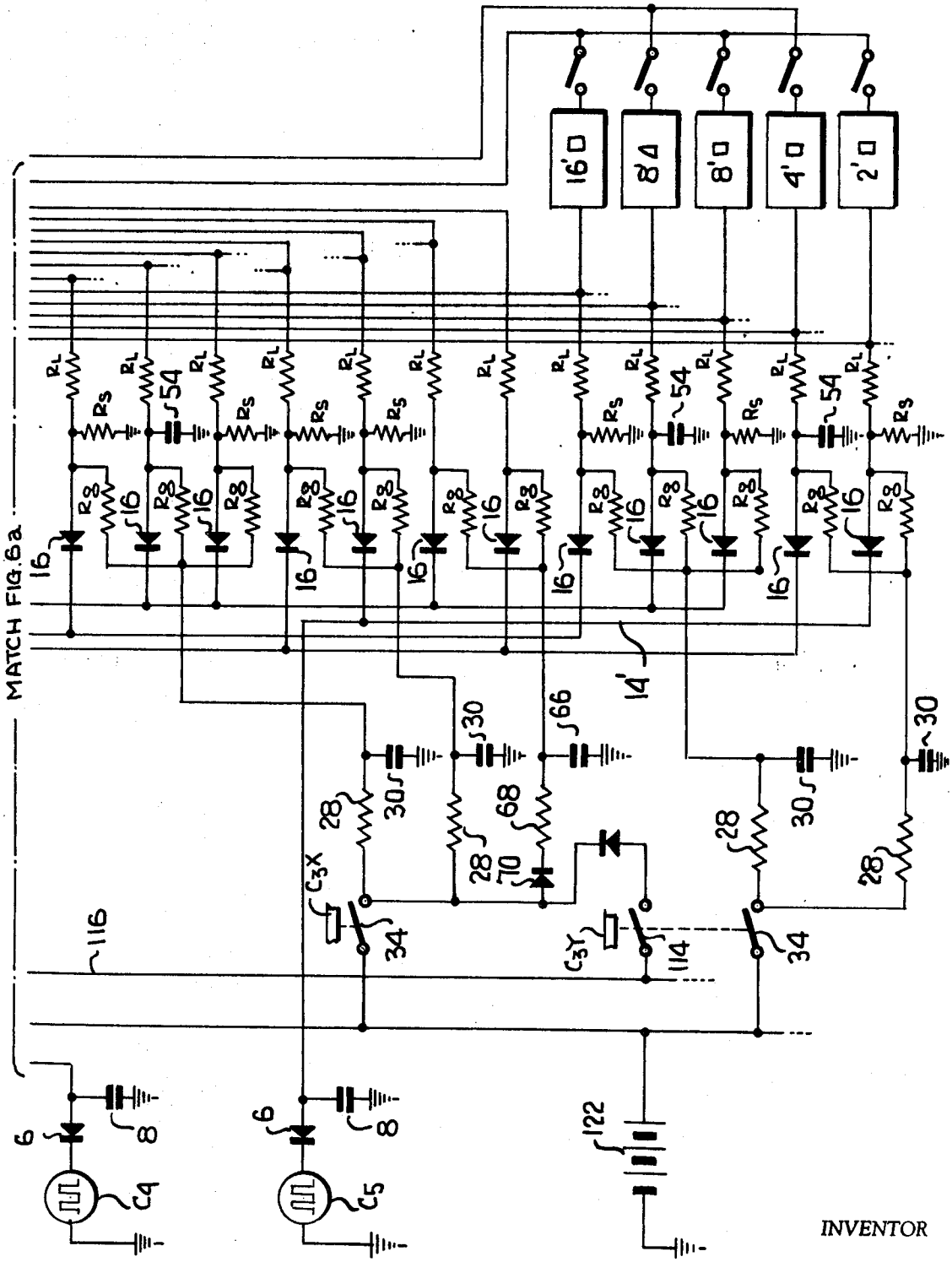


FIG.6b

INVENTOR
DALE M. UETRECHT

BY William H. Bruning, Agent

DIODE KEYING SYSTEM FOR ELECTRONIC ORGAN

BACKGROUND OF THE INVENTION

An inherent disadvantage of the variable-resistance-key-switch system for electronic organs is that the large number of decks of key switches required in large organs must be located between manual keyboards, where limited space is available. Also, there is no provision for scaling the attack and decay of tones throughout a gamut other than the rate at which the keys are depressed and released. Further, coupling between keyboards is required. This necessitates that each manual have the same footages and wave shapes available as the keyboard to which it is coupled.

In general, this limits the tone color variety between keyboards. Therefore, the principal objects of this invention are (1) to obtain a simple gate arrangement to minimize the number of switch decks, (2) to obtain desirable attack and decay character, (3) to obtain simple and complete coupling and (4) to obtain a wide variety of tone colors, while maintaining the cost advantage of a key switch system. Another object is to utilize the economic advantage of a distributed filter system of tone color filters over a currently used active filter system in which five active filters are required for a five-octave keyboard at approximately twice the cost of an RC distributed filter as disclosed in a copending application Ser. No. 738,024 in the name of Dale M. Uetrecht and filed June 18, 1968. This system comprises a distributed filter of discrete components, groups of tone signals being introduced along the filter, so that multiple inputs exist, the entire output being taken from one point. A *gated* system such as that of the present application, provides an economical coupling system by which the signal may be coupled prior to signal collection points by means of DC switching. Therefore, the other advantages of a distributed filter system can be utilized without switching at about 10 collector points.

Prior art relevant to the present invention consists principally of U.S. patents to:

George 2,483,823
Munch et al. 3,223,768
Munch et al. 3,321,567
Bissonette et al. Ser. No. 541,380.

George disclosed a vacuum diode keying circuit for an electronic musical instrument, which required a separate bias source for the diode. The Munch et al. patents show how to self-bias a single or double, solid-state diode gate with the aid of a coupling capacitor between the tone signal source and the gate, the latter patent being a continuation-in-part of the former. The latter Munch et al. patent expands the teachings of the former with respect to wave-shaping in a diode gate. The Bissonette et al. application will be discussed hereinafter.

With this prior art as background, the various aspects of this invention arose as solutions to three problems in developing a practical diode keying system. First, since a diode gate is a nonlinear device, it is necessary to isolate the gate of one tone signal frequency from the gate of another tone signal frequency to minimize intermodulation distortion. In some "percussion" gating systems an appreciable amount of intermodulation distortion is tolerated, or elaborate filtering is provided to minimize output distortion. However, in a complete gating system for an organ, it is necessary to reduce intermodulation distortion to about 0.1 percent without resorting to the cost of elaborate tone color filtering.

The second problem is "leakthrough." This may be defined as the ratio of output signal present when a gate is *off* compared with the output signal present when the gate in on. The general requirement for leakthrough is −80 db. up to 8000 Hertz. Diodes are presently available with stray capacitance of the order of 1 pf., but it is desirable to use lower-cost diodes having approximately 10 pf. stray capacitance. At 8000 Hertz a 1 pf. capacitor has an impedance of 20 megohms. Therefore, a 1 pf. diode would require a 2-kilohm ON impedance. This requires unrealistic gate current to achieve low leakthrough. Therefore, it is necessary, except for low-capacitance diodes,

to use two diodes in series (one isolating diode and one keying diode) to obtain the desired leakthrough isolation. Munch taught in the referenced U.S. Pat. No. 3,223,768 the practice of using two diodes in series with a bypass impedance shunted between them to reduce leakthrough, but his disclosure was that of a single gate containing the two diodes and a bypass impedance.

The third problem is to provide two basic wave shapes which can be filtered in the output system to obtain desired tone colors. One must be a square wave, having only odd-order harmonics and preferably $1/n$ amplitude, where n is the harmonic number. The second is an all-harmonic wave shape, again with $1/n$ amplitude. Usually a linear saw tooth is used for the all-harmonic wave, as it contains harmonics at $1/n$ amplitude. To obtain a linear saw tooth it is necessary to discharge a capacitor during a small fraction of a cycle and allow it to charge from the keyed source for the remainder of the cycle. However, since more components are required to obtain this wave shape, an alternate wave shape was analyzed and found to have essentially the same harmonic structure. The latter wave shape is achieved by clamping a capacitor at one potential for a half period of a square wave input and allowing the capacitor to charge toward another potential for the remaining half period.

The referenced copending patent application of Bissonette et al., entitled Electronic Organ Gating System, Ser. No. 541,380, filed Apr. 8, 1966, now abandoned and assigned to the assignee of this application, sets fort a basic approach to the solution of the second of the above problems. In the cited reference, use is made of a common isolating diode gate for each source of tone signal, followed by a double-diode keying gate employed for each footage in a given keyboard. However, the teachings of Bissonette and Munch are silent on the subject of intermodulation distortion. Also, no provision is taught for achieving more than one wave form at the output of keying diode gates turned on by a single key switch. Furthermore, there were no teachings as to coupling the tone color filters normally associated with one keyboard with the key switches of another keyboard. Likewise no mention was made for the scaling of attack networks throughout a gamut.

SUMMARY OF THE INVENTION

The isolating diode gate associated with each tone signal source comprises a series diode having a stray capacitance of the order of 10 pf. and a shunt capacitor of about 1000 pf., providing 40 db. isolation. An additional 40 db. isolation is easily obtained across each of the paralleled keying diode gates, which comprise each a second diode in series next to the isolating diode, the second diode being followed in series by a relatively high resistor to which is connected a collector for the other tone signals which may be directed through other gates to a particular tone color filter in the output system. This collector, in turn, is shunted to ground by a relatively-low resistor. Therefore, the common collector is isolated from the nonlinearity of the keying diode gate by virtue of the relatively high series output resistor of the gate, thereby minimizing intermodulation distortion. Forward biasing potential for both diodes is applied at the junction between the second diode and the relatively high series resistor via the series combination of a direct current potential source, a key switch, and R–C attack network and a resistor, the latter being connected to the junction. The R–C attack network comprises a further series resistor followed by a shunt capacitor, the latter two components being scaled throughout the gamut of the system to provide shorter attack for the higher notes and a longer one for the lower notes. A common R–C attack network for a given key switch controls the envelope of the signals passing through several of the keying diode gates corresponding to that switch. (These networks are called "attack networks," because the decay of the signals is relatively unimportant—so long as it is not too long or too abrupt—in view of the face that reverberation of the organ tones in a playing environment sub-

stantially mass the decay portion of the tone signals themselves.)

Tone signals for percussive voices are passed through gates similar to those just described. However, another diode isolates the R–C attack network from other simultaneously keyed signals in order to obtain a sustained envelope of percussion signals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially block, partially schematic diagram of a circuit providing a single path for a tone signal from a source thereof through isolating and keying gates to an output system, according to the invention.

FIG. **1***a* is a partially block, partially schematic diagram of an alternative to a portion of the diagram of FIG. **1**.

FIG. **2** is a diagram similar to FIG. **1**, except that the keying gate has provision for wave-shaping.

FIG. **3** is a graph illustrating wave forms present in the embodiment of FIG. **2**.

FIG. **4** is a partially block, partially schematic diagram of the parallel combination of the keying diode gates of FIGS. **1** and **2**, plus a keying diode gate for a "percussive" signal, all being connected between a common signal source and separate tone color circuits to amplification and transducing means.

FIG. **5** is a partially block, partially schematic diagram of circuits providing tone signal paths from two frequency-adjacent tone sources in two adjacent octaves through gates to the output system of an electronic organ in accordance with the invention.

FIGS. **6***a* and **6***b* together comprise a partially block, partially schematic diagram of the signal path and keying circuits for five of the octavely related sources of an exemplary organ.

FIG. **7** is a chart giving practical values for certain components in a complete organ system derived from the teaching of FIGS. **5**, **6***a* and **6***b*.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. **1** a tone signal source **2**, preferably supplying positive-going square waves, such as may be derived from one stage of a chain of frequency dividing flip-flops, is connected to an isolating diode gate **4**, comprising a series diode **6** (preferably a low-cost solid-state one), and a shunt capacitor **8**, the source **2** and capacitor **8** being grounded, as shown, to a common return path. The junction **10** of the diode **6** and capacitor **8** is connected to a keying diode gate **12** via a branch **14**, indicating where additional keying diode gates (not shown) may be connected. The gate **12** comprises a series diode **16**, a relatively high, voltage-dropping series resistor **18** and another resistor **20** connected at the junction **22** of the diode **16** and resistor **18**. One end of a further resistor **24** is connected, if needed (for reasons discussed hereinafter), between the junction **22** and a common return path as shown. To the other end of the resistor **20** is connected an R–C attack network **26** composed of a series resistor **28** and a shunt capacitor **30**. The branch **32** indicates where additional keying gates (not shown) may be connected. The resistor **26** is connected via a key switch **34** to a source of direct current potential (not shown) having a positive terminal **36**. A branch **38** indicates where other attack networks (not shown) may be connected.

The output end of the resistor **18** is connected via branch **40** and branch **42** to an output system **44**, composed of a tone color filter TC_1, a stop switch **45**, branch **46**, amplifier **48** and loudspeaker **50**, all in series. The speaker **50** is preferably of the rotary, Doppler-effect type. The branch **40** indicates where additional keying gates (not shown) may be connected; the branches **42** and **46** show where connections may be made to additional tone color filters (not shown). The branch **42** is shown connected to a common return path via a relatively-low resistor **52** (that is, relatively low compared with relatively high resistor **18**). Practical values are 100 kilohms for resistor **18** and 1—2 kilohms for resistor **52**.

In operation, when the switch **34** is in the *off* position (as shown), positive-going square waves from the source **2** are blocked by the diodes **6** and **16**, and maximum isolation exists between the source **2** and the output system **44**. When the switch **34** is turned on, the DC potential V+ at **36** starts to charge the capacitor **30** via the resistor **28** in the attack network **26**. As the DC potential across the capacitor **8** builds up, it is applied to the diodes **6** and **16** causing them to conduct via the resistor **20** and the source **2**. As the conductivity of the diodes increases, the square-wave signal passes through the diodes **6** and **16** and on to the output system **44**, where it is modified in tone color by the filter TC_1 and flows to the amplifier **48** and loudspeaker **50**, when the tone-color switch **45** is closed. Obviously, the signal may be interrupted by opening the switch **45**. When the key switch **34** is opened, the signal will decay as the resistivity of the diodes **6** and **16** increases. Those skilled in the art will realize that attack and decay rates of the signal will be determined principally by the time constant of resistors **20** and **28** and capacitor **30**. The network **26** is called an "attack network," as mentioned above, the decay rate being less critical because of the masking of the decay of a tone by reverberation in the usual environment surrounding the loudspeaker **50**.

The shunt capacitor **8** offers a relatively low-impedance path relative to the off-impedance of the diode **6**, thus providing a shunt path for leakthrough from diode **6**. However, the capacitor **8** is a relatively high impedance compared with the on-resistance of the diodes **6** and **16**. Thus the *on* signal is not substantially bypassed by the capacitor **8**. The shunt resistor **24** is not essential to the *operation* of the keying diode gate **12**, but it not only contributes to feed-through reduction, but, also, it may be utilized to vary the signal attack when the same attack network is used for another keying gate, (as will be discussed more fully hereinafter).

In the diagram of FIG. **1***a*, the dashed-line block **49** represents an alternative to the source **2** and gate **4** and comprises portions of an integrated circuit. One flip-flop circuit **2***a* in a chain thereof has a connection to a buffer amplifier **4***a* comprising an MOSFET having an output lead **51**. A square wave is present at all times at **53**, while on the lead **51**, there is a wave-shaped signal when keying current is present. No signal is present in absence of keying voltage. If this configuration is used, the diode **16** of FIG. **1** will be reversed and the keying voltage at **36** will be negative. Thus, it is not intended that this invention be limited to a *diode* isolating gate. Any equivalent gate providing the necessary isolation and operable by the keying voltage may be used.

The circuit of FIG. **2** is similar to that of FIG. **1**, except that (1) a shunt timing capacitor **54** replaces the resistor **24** and (2) tone color filter TC_2 replaces TC_1.

In operation, however, the keying diode gate is reverse biased during the positive-going half of every cycle. Thus the wave shape of the signal at junction **22** is altered by the capacitor **54**. Reference is made to the graph of FIG. **3** for an explanation of the change in wave shape.

In FIG. **3** signal voltage is plotted against time. At time t_1 the positive excursion **55** of the source signal increases abruptly to its maximum at Y_1 and remains there until time t_2. During this half cycle of the square wave, the voltage across the capacitor **54** rises exponentially forming a ramp, as at **56**, (the time constant being determined principally be the resistor **20** and capacitor **54**) until time t_2 when the square wave drops abruptly back to zero voltage. If the capacitor **54** where allowed to charge to a level v_2, it would follow the curve, as at **58**, and approach v_2 asymptotically. The dashed line **60** shows an extension of a true "sawtooth" for the half cycle shown. For the remainder of the period, the voltage across the capacitor remains at zero. If the time constant of the circuit including the capacitor **54** and the total resistance of the path through which it is charged, is made equal to the period of one cycle of the wave, the relative harmonic structure of the modified sawtooth is nearly the desired $1/n$. Actually, the fundamental is $1.28/n$ (where $n=1$), the third harmonic is $1.04/n$ (where $n=3$) and the record and higher harmonics are approximately $1/n$.

Thus, if the keying diode gates of FIG. 1 and FIG. 2 are paralleled following a common isolating diode gate and a common attack network, square waves and sawtooths will be available from a single source, keyed by means of a single key switch. This combination is illustrated in FIG. 4, wherein some of the elements similar to those of FIGS. 1 and 2 are similarly designated. In FIG. 4 the keying gates 12 and 12' have a common input through the branch 14' from the common source 2 and isolating gate 4. Also, a common attack network 26 is connected to keying gates 12 and 12' via branch 31'. The outputs of the keying gates 12 and 12' are directed, as shown, via TC_1 and TC_2, respectively, to collectors 46' and 61, amplifiers 48 and 63, and loudspeakers 50 and 65, respectively. In addition is provided a separate attack network 62 and keying diode gate 64 for "percussive" signals (i.e., signals having an abrupt attack and gradual decay). To achieve these characteristics of percussion, the sustain capacitor 66 will be larger than the capacitor 30, while the resistor 68 will be smaller than resistor 28. The sustain isolating diode 70 prevents the decaying percussive signal from passing back through the keying gates 12 and 12', thereby allowing a long-sustain percussion signal and short-sustain nonpercussive signal. The signal from the gate 64 (similar to gate 12, except for omission of a resistor corresponding to resistor 24 of gate 12) is passed by branch 72 (for other keying gates, not shown) and branch 74 (for other tone color filters, not shown) to tone color filter TC_3, appropriate for a percussive voice, as known in the art. The output of the filter TC_3 may be switched by stop tab switch 76 to the collector 46' for signals to be amplified by amplifier 63 and radiated preferably by the rotary loudspeaker 65. A relatively-low resistor 80 provides the path to ground for the branch 74.

In operation, square wave signals form the source 2 of FIG. 4 are blocked by gates 4, 12, 12' and 64 until keyed on by switch 34. The signal passes through gates 12 and 12' respectively, as activated by common attack network 26 in a manner similar to that of FIGS. 1 and 2. At the same time, signal passes via branch 14' to gate 64, which is activated by +V via the same key switch 34 but the separate attack network 62. The square wave signal passes through the gate 64 without alteration, except that it decays slowly when the switch 34 is opened. As mentioned above, both the direct current keying voltage and signal through the gate 64 are blocked by diode 70 from passing though any path except through resistor 82 which is sufficiently high to cause a gradual decay. Thus in FIG. 4 is illustrated the basic circuitry for developing a complete organ system.

The problem of intermodulation distortion will be discussed in conjunction with FIG. 5, which shows square wave keying gates for two consecutive notes in two adjacent octaves of an exemplary instrument. This also teaches the means for obtaining adjacent footages simultaneously from a common key switch. Referring to FIG. 5, sources C_1 and C_2 are the lowest two octavely related sources, while sources $C0_1$ and $C0_2$ are respectively a semitone higher. Isolating gate 84 couples source C_2 to keying gate 86, containing diode 85 and resistor 87, to the junction of which is connected, via resistor 83, attack network 88, which in turn is connected by way of key switch 90 to a direct current bus 92 supplied with direct current potential by a source 94 thereof. Further, attack network 88 has a connection via line 96 to a second keying gate 98 the input side of which is coupled, as shown, to source C_1 via isolating gate 100. The keying gate 86 is shown having an output connection past branches 89 and 91 (the latter having a grounding resistor 93) to a tone color filter 8' TC, which, in turn, may be connected via tab switch 102 to collector 103 for signal being passed to amplifier 104 and loudspeaker 106. The keying gate 98 has an output connection past branch points to a further tone color filter 16' TC, which, in turn may be connected via tab switch 108 to collector 103 for signals being passed to amplifier 104 and 106.

Those portions of the system of FIG. 5 pertaining to simultaneously producing 8' and 16' tones operate as follows. Closure of the key switch 90 directs activating potential to the isolating gates 84 and 100 and keying gates 86 and 98 by way of common attack network 88. The outputs of the keying gates 86 and 98 are filtered by filters 8' TC and 16' TC, respectively, and upon closure of tab switches 102 and 108, respectively, for amplification by amplifier 104 and loudspeaker 106.

Also, there is illustrated in FIG. 5 the circuitry for obtaining two adjacent semitones. The circuitry for C_2 has just been described. In a similar manner the source $C0_2$ is connected via isolating gate 108 to keying gate 110, containing diode 109 and resistor 111, which, in turn, is connected to collector 112 which has a connection to tone color filter 8' TC, where the path to loudspeaker 106 is the same as for the output of keying gate 86. The operation of the path of the signal from $C0_2$ is similar to that of the path for C_2. However, it is pointed out that in the collector 112, there is the combination of nonharmonically related signals. This is a condition where intermodulation distortion can become a problem. This intermodulation is kept at a minimum by making the value of the resistors 87 and 111 large compared to the cyclic variation of the impedance looking back therefrom through their respective pairs of gating diodes to the sources C_2 and $C0_2$ respectively. Also, the resistor 93 is made low compared with resistors 87 and 111. The latter resistors may be of the order of 100 kilohms and the resistor 93 about 1 to 2 kilohms. Keying gate resistors such as 83 and 107 are preferably scaled small at higher frequencies to keep the leakthrough down and high at lower frequencies to keep wave-shaping capacitors such as 54 (FIG. 2) at a convenient size. Also, by scaling resistors such as 83 and 107, the attack network capacitors such as 30 (FIG. 4), may be the same value for a whole keyboard. It was found that the random variations in attack rate which resulted from +80 percent, −20 percent electrolytic capacitors were not generally noted. These random variations blend in to an average effect.

In FIGS. 6*a* and 6*b* there is illustrated typical circuitry for five consecutive C notes in an organ system, including interkeyboard coupling, sharing of attack networks by adjacent-footage signals and sharing of isolating gates. The five corresponding sources are indicated as C_1 to C_5, inclusive. To these sources are connected isolating diodes 6 (indicia correspond to FIGS. 1 and 2), with capacitors 8 shunting them, as shown. From the junction of each capacitor 8 and diode 6, connection is made to a branch 14' from which further connection is made to all the keying diode gates for a given signal frequency, and being composed of a series diode 16, series resistor R_L, gating resistor R_g, shunt resistor R_s (or shunt capacitor 54). To R_g is connected, as taught in preceding figures an attack network composed of series resistor 28 and shunt capacitor 30, except for the percussive gates, whose series resistors are labeled 68 and whose capacitors are marked 66. The resistors 28 have connections respectively to key switches 34, which are actuable by playing keys labeled C_2X, C_3X in one keyboard and C_2Y, C_3Y in *another* keyboard. The attack resistors 68 (for percussive notes) are isolated from their respective key switches 34 by diodes 70, respectively. Keys C_2Y and C_3Y have ganged thereto (along with switches 34), auxiliary switches 114, which have a common connection 116 to an interkeyboard coupler switch 118, preferably actuated by a stop tab 120.

Continuing with FIGS. 6*a* and 6*b*, the input side of resistors R_L have the previously-mentioned grounded shunt resistors (corresponding to resistor 24 in FIG. 1) R_s respectively connected thereto. To the output side of the resistor R_L there is a first branch (for other parallel gates, not shown) and a second branch (for other tone color filters, not shown). To the second branch for each output lead is connected a tone color filter corresponding to the TC's of FIG. 4. Each filter in FIGS. 6*a* and 6*b* is designated with the footage of the processed signal plus a block or a triangle, indicating whether the filter is for a square wave or a sawtooth, respectively. Tab-operated stop switches such as those designated 45, 59, and 76 are respectively the switches for square wave, sawtooth and percussion

voices (as in FIG. 4). To the stop switches for square wave and percussive voices is preferably connected an output collector **46'** to which are connected amplifier **48** and rotary loudspeaker **50**. The sawtooth wave filters are shown connected via output collector **61** to amplifier **63** and stationary speaker **65**.

In operation, the signals respectively are blocked by isolating diode gates each having components consisting of diode **6** and capacitor **8** and by the keying diode gates each having components such as diode **16** and resistors R_g, R_L and R_s (or capacitor **54**, if for sawtooth signal). Activating direct current for both types of gates is provided by attack networks each composed of a resistor **28** and a capacitor **30**, except for percussion. The percussion signals are keyed-on through such attack networks as those composed of series resistor **68** and shunt capacitor **66**. The isolating diodes **70** serve the same purpose as diode **70** in FIG. **4**. It will be noted that a single key switch **34** (for key C_2X, for example) keys direct current from source **122** thereof to *three* attack networks **124, 126** and **127**. Network **124** activates keying gates **128, 130** and **132** for **8'** and **16'** voices at a relatively slower rate than does network **126** activate keying gates **134** and **136** for **4'** and **2'** voices. (It is, of course, characteristic of pipe organs that lower-pitched pipes in a given rank speak more slowly than higher-pitched pipes). A still more abrupt attack is preferably provided by attack network **127** for percussive voices, via keying gates **138** and **140**. It can be seen that a single attack network can be comprised to provide acceptable rise time for tone signals of adjacent footages. It can also be seen that tracing signal paths keyed by key C_3X (an octave higher than C_2X) that output signals will pass to the same filters as those for C_2X.

The signal and DC paths for keys C_2Y and C_3Y (in a keyboard Y) are shown as similar in arrangement and operation to those for C_2X and C_3X, except that no percussion is provided. However, the previously-mentioned coupler switch **118**, if closed, makes direct current available through auxiliary switches **114**, so that direct current corresponding to notes played on the Y keyboard will be directed, for example, via diode **141** and lead **142** to the same attack networks **124, 126** and **127** which are normally effective when C_2X is depressed. Thus is provided a simple one-switch coupler arrangement. The diode **141** obviously isolates key switches **114** from key switches **34** in the reverse direction.

In FIG. **7** are given the scaled values for R_g, R_s and capacitor **54** in the system of FIGS. **6***a* and **6***b*. For example, the capacitor **54** is 0.12 mf. in the sawtooth keying gates for lowest three notes (C, C0 and D) of the first (lowest) octave in the gamut. The next higher three notes (D0, E and F) use a 0.10 mf. capacitor **54**. The signals for the highest octave are from the master oscillators in a frequency-divider chain of flip-flops previously mentioned and no capacitors **54** are needed, since most of the harmonics are available in the master oscillator wave form.

As has been previously mentioned, use of low-cost 10 pf. diodes necessitates two diodes in series to obtain the desired leakthrough isolation. It has been shown how a single diode on each source output can be shared by as many keying gate diodes as desired, so long as other leakthrough requirements are met. When no gates are operated in their *on* condition, the isolating diode provides 40 db. isolation by means of the capacitor divider (that is, the 10 pf. stray capacitance of the diode shunted by a 1,000 pf. capacitor). An additional 40 db. isolation is easily obtained across the keying gate diode. However, when the shared isolating diode gate is operated by one keying gate, the 40 db. isolation is lost with respect to a parallel keying gate which is not *on*. The isolation of this keying gate must then be able to take care of "sneak" paths. One such path occurs when a subharmonic signal is gated on at a lower footage that is not stop-tabbed and leaks across the keying gate in a lower octave of the footage that is stop-tabbed. Another possible sneak path occurs when an isolating diode is turned *on* from one keyboard at a frequency *not* tabbed and leaks across the keying gate of a second keyboard where that frequency is tabbed. Therefore an isolation between 40 and 60 db. is required for the keying gate, or an impedance of from 2 to 20 kilohms at 8,000 Hertz when 10 pf. diodes are used. The actual impedances were sealed down to 15K at 8,000 Hertz to maintain reasonable keying currents, and 1 pf. diodes were used in a few cases where additional isolation was required.

Thus the primary objective of obtaining a simple, and therefore economical gating system has been accomplished. As a result of using a gating system, controlled attack and direct coupling is obtained. In addition to simplicity, a significant virtue of the gate of the present invention is that two desirable wave shapes can be obtained. As a direct result of the wave shapes available, and the direct coupling, a wide variety of quality tone colors can be obtained using the simple distributed filters previously mentioned.

For the purposes of the claims, a "keying network" comprises an isolating gate, one or more keying gates connected in parallel thereto, an attack-network with associated key switch and direct current source. An "activating circuit" is composed of an attack network, a key switch and a direct current source.

Although this specification includes isolating gates for each source, so that higher-stray-capacitance, low-cost diodes can be used, it will be obvious to one skilled in the art that higher-cost, lower-stray-capacitance diodes may obviate the necessity of *isolating* gates. This does not detract from the utility of the *keying* gates of the present application which in themselves are believed new and useful in the art for the purposes described.

While I have described and illustrated specific embodiments of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. An electronic music system having in cascade a continuous tone signal source, a keying network and an output system, said keying network comprising in combination:

an isolating gate coupled to said signal source,

a first and a second keying gate in parallel between said isolating gate and said output system, said second keying gate having wave-shaping characteristics different from those of said first keying gate, and

a common activating circuit for both said gates respectively coupled to said first and said second keying gates.

2. The combination according to claim **1** wherein said activating circuit includes in cascade with a source of direct current potential:

a key switch and

a first R–C attack network coupled respectively to said first and said second keying gates.

3. The combination according to claim **2** wherein said signal source supplies square waves, wherein said first keying gate is arranged and adapted to pass said square waves substantially without change in shape, wherein said second keying gate is arranged and adapted to shape said square waves substantially into sawtooth waves and wherein said output system includes:

a first tone color filter coupled to said first keying gate and

a second tone color filter coupled to said second keying gate.

4. The combination according to claim **2** including:

a third keying gate in parallel with said first and said second keying gate between said isolating gate and said output system, and

a second R–C attack network coupled between said key switch and said third keying gate.

5. The combination according to claim **3** wherein said first keying gate comprises the combination of:

a first diode coupled to said isolating gate,

a first relatively high resistor in series with said first diode and said first tone color filter,

a second relatively-low resistor shunted between a common return path and the junction between said first resistor and said first tone color filter, said relatively-low resistor

being of the order of two magnitudes lower than said relatively high resistor; and

a third voltage-dropping resistor between said first attack network and the junction between said first diode and said first resistor.

6. The combination according to claim 3 wherein said second keying gate comprises the combination of:

a first diode coupled to said isolating gate,

a first relatively high resistor in series with said first diode and said second tone color filter,

a capacitor shunted between a common return path and the junction between said first diode and said first resistor,

a second voltage-dropping resistor between said junction and said first attack network and

a third relatively-low resistor shunted between the common return path and the junction between said first resistor and said second tone color filter, said relatively-low resistor being of the order of two magnitudes lower than said relatively high resistor.

7. The combination according to claim 4 wherein said signal source supplies square waves, wherein said first keying gate passes said square waves substantially without change in shape, wherein said second keying gate shapes said square waves substantially into sawtooths, wherein said third keying gate passes said square waves substantially without change and wherein said output system includes:

a first tone color filter for square waves coupled to said first keying gate,

a second tone color filter for sawtooths coupled to said second dyeing gate and

a third percussive tone color filter coupled to said third keying gate.

8. The combination according to claim 4 wherein a first diode is coupled between said key switch and said second R–C attack network and wherein said third keying gate comprises the combination of:

a second diode coupled to said isolating gate,

a first relatively high resistor between said second diode and said output system,

a second voltage-dropping resistor between said second R–C attack network and the junction between said second diode and said first resistor and

a third relatively-low resistor shunted between the common return path and the junction between said first resistor and said output system, said relatively-low resistor being of the order of two magnitudes lower than said relatively high resistor.

9. The combination according to claim 7 wherein said first keying gate comprises the combination of:

a first diode coupled to said isolating gate,

a first relatively high resistor between said first diode and said first tone color filter,

a second relatively low resistor shunted between a common return path and the junction between said first resistor and said first tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor,

a third voltage-dropping resistor between said first attack network and the junction between said first diode and said first resistor, wherein said second keying gate comprises the combination of:

a second diode coupled to said isolating gate,

a fourth relatively high resistor in series with said second diode and said tone color filter,

a capacitor shunted between said common return path and the junction between said second diode and said fourth resistor; and

a fifth resistor between said last-mentioned junction and said first R–C attack network, and wherein a third diode is coupled between said key switch and said second R–C attack network and wherein said third diode keying gate comprises the combination of:

a fourth diode coupled to said isolating gate,

a sixth relatively high resistor between said fourth diode and said third tone color filter,

a seventh resistor between said second R–C attack network and the junction between said fourth diode and said sixth resistor,

an eighth resistor between said last-mentioned junction and said common return path and

a ninth relatively low resistor shunted between the common return path and the junction between said sixth resistor and said third tone color filter, said ninth relatively low resistor being of the order of two magnitudes lower than said sixth relatively high resistor.

10. An electronic music system having a first continuous tone signal source, a second continuous tone source, an output system, a first keying network between said first tone signal source and said output system, and a second keying network between said second tone signal source and said output system, said keying networks each comprising:

an isolating gate coupled to its corresponding tone signal source,

a first keying gate coupled between said isolating gate and said output system, and

an activating circuit for the gates in each of said keying networks, each first keying gate comprising:

a first diode and a first relatively high resistor in series between its corresponding isolating gate and said output system,

a second voltage-dropping resistor between said common activating circuit and a first junction between said diode and said first resistor and

a third relatively low resistor shunted between a common return path and a second junction between said first resistor and said output system, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor,

wherein said keying networks each include a second keying gate in parallel with said first keying gate, each second keying gate comprising:

a second diode and a fourth relatively high resistor in series between its corresponding isolating gate and said output system,

a fifth voltage-dropping resistor between said common activating circuit and said first junction,

a capacitor coupled between said common return path and said first junction,

and a sixth relatively low resistor between said common return path and said second junction, said relatively-low resistor being of the order of two magnitudes lower than said relatively high resistor.

11. In an electronic music system, the combination comprising:

a continuous tone signal source,

an isolating gate coupled thereto,

an output system,

four keying gates in parallel between the isolating gate and the output system, the first of the keying gates having different wave-shaping characteristics from the second of the keying gates, the third of the keying gates having correspondingly different wave-shaping characteristics from the fourth of the keying gates,

a first common activating circuit for the isolating gate and for the first and second keying gates respectively coupled to the first and second keying gates and

a second common activating circuit for the isolating gate and for the third and fourth keying gates respectively coupled to the third and fourth keying gates.

12. The combination according to claim 11, wherein each of the activating circuits include in cascade:

a common source of direct current potential,

a key switch and

an R–C attack network coupled to the keying gates corresponding thereto.

13. The combination according to claim 11, wherein the tone signal source supplies square waves, wherein the first and third keying gates pass the square waves substantially without change in shape, wherein the second and fourth keying gates shape the square wave substantially into sawtooths and wherein the output system includes:
a first tone color filter coupled to the first and third keying gates and
a second tone color filter coupled to the second and fourth keying gates.

14. The combination according to claim 13, wherein the R–C attack networks have different characteristics.

15. The combination according to claim 13, wherein the key switch in the first of the activating circuits corresponds to a key in a first keyboard and the key switch in the second of the activating circuits corresponds to a key in a second keyboard.

16. The combination according to claim 13, wherein said first and third keying gates each comprise the combination of:
a first diode coupled to the isolating gate,
a first relatively high resistor in series with the first diode and the first tone color filter,
a second relatively low resistor shunted between a common return path and the junction between the first resistor and the first tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor,
a third resistor between the attack network in the first activating circuit and the junction between the first diode and the first resistor.

17. The combination according to claim 13, wherein the second and fourth keying gates each comprise the combination of:
a first diode coupled to the isolating gate,
a first relatively high resistor in series with the first diode and the second tone color filter,
a capacitor shunted between a common return path and the junction between the first diode and the first resistor,
a second voltage-dropping resistor between the junction and the second attack network and
a third relatively low resistor shunted between the common return path and the junction between the first resistor and the second tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor.

18. The combination according to claim 15, including:
a third key switch ganged to the key switch in the first of the activating circuits,
a coupler switch connected between the source of direct current potential and the third key switch.

19. The combination according to claim 18, including:
a first diode between the third key switch and the first of the activating circuits.

20. In an electronic organ, the combination comprising:
a gamut of tone signal sources,
a plurality of isolating gates respectively coupled to said signal sources,
a plurality of keying gate groups, each plural group comprising gates coupled in parallel to each of said isolating gates, said keying gates of a group having different wave shaping characteristics one from the other,
a plurality of activating circuits each circuit coupled to control conduction through a different group of said keying gates, and
an output system coupled to said keying gates.

21. The combination according to claim 20 wherein each activating circuit includes in cascade with a source of direct current potential:
a key switch and
a first R–C attack network coupled to said at least two keying gates.

22. The combination according to claim 21 wherein said signal sources supply square waves, wherein the first of said at least two keying gates passes square waves substantially without change in shape, wherein the second of said at least two keying gates shapes said square waves substantially into sawtooths and wherein said output system includes:
a first tone color filter coupled to all said first keying gates and
a second tone color filter coupled to all said second keying gates.

23. The combination according to claim 21 including:
a plurality of third keying gates each in parallel with said at least two keying gates and a plurality of second R–C attack networks respectively coupled between each key switch and each of said third keying gates.

24. The combination according to claim 22, wherein each of said first keying gates comprises the combination of:
a first diode coupled to its corresponding isolating gate,
a first relatively high resistor in series with said first diode and said first tone color filter,
a second relatively low resistor shunted between a common return path and the junction between said first resistor and said first tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor, and
a third voltage-dropping resistor between said first attack network and the junction between said first diode and said first resistor.

25. The combination according to claim 22, wherein each of said second keying gates comprises the combination of:
a first diode coupled to its corresponding isolating gate,
a first relatively high resistor in series with said first diode and said second tone color filter,
a capacitor shunted between a common return path and the junction between said first diode and said first resistor,
a second voltage-dropping resistor between said junction and said first attack network, and
a third relatively low resistor shunted between the common return path and the junction between said first resistor and said second tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor.

26. The combination according to claim 23 wherein said signal sources supply square waves, wherein each of said first keying gates pass said square waves substantially without change in shape, wherein each of said second keying gates shapes said square waves substantially into sawtooths, wherein each of said third keying gates passes said square waves substantially without change and wherein said output system includes:
a first tone color filter for square waves coupled to said first keying diode gates,
a second tone color filter for sawtooths coupled to said
a third tone color filter for percussion coupled to said third keying gates.

27. The combination according to claim 23 wherein a first diode is coupled between each of said key switches and each of said second R–C attack networks and wherein each of said third keying gates comprises the combination of:
a second diode coupled to its corresponding isolating gate,
a first relatively high resistor between said second diode and said output system,
a second voltage-dropping resistor between said second R–C attack network and the junction between said second diode and said first resistor,
a third relatively low resistor shunted between the common return path and the junction between said first resistor and said output system, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor.

28. The combination according to claim 26 wherein each of said first keying gates comprises the combination of:
a first diode coupled to its corresponding isolating gate,
a first relatively high resistor between said first diode and said first tone color filters,

a second relatively low resistor shunted between a common return path and the junction between said first resistor and said first tone color filter, said relatively low resistor being of the order of two magnitudes lower than said relatively high resistor,

a third voltage-dropping resistor between said first attack network and the junction between said first diode and said first resistor, wherein each of said second gates comprises the combination of:

a second diode coupled to its corresponding isolating gate,

a fourth relatively high resistor in series with said second diode and said tone color filter,

a capacitor shunted between said common return path and the junction between said second diode and said fourth resistor, and

a fifth voltage-dropping resistor between said last-mentioned junction and said first R–C attack network, wherein a third diode is coupled between said key switch and said second R–C attack network and wherein each of said third keying gates comprises the combination of:

a fourth diode coupled to its corresponding isolating gate,

a sixth relatively high resistor between said fourth diode and said third tone color filter,

a seventh voltage-dropping resistor between said second R–C attack network and the junction between said fourth diode and said sixth resistor,

an eighth resistor between said last-mentioned junction and said common return path, and

a ninth relatively low resistor shunted between the common return path and the junction between said sixth resistor and said third tone color filter, said ninth relatively-low resistor being of the order of two magnitudes lower than said sixth relatively high resistor.

29. In an electronic organ,

a source of periodic square wave tone signals which alternate between a first and a reference level,

a single isolating gate, which is nonconductive of signals when unbiased, connected in cascade with said source,

a plurality of solid-state electronic keying gates connected in parallel with each other and all connected in series with said single isolating gate,

a single key operated switch for applying DC bias voltage concurrently through all said gates and through said source to a reference point, and

different circuits connected between said key operated switch and each separate one of said keying gates, one of said different circuits being responsive to said square wave signals for generating correspondingly shaped square waves, and

another of said different circuits being responsive to said square wave signals for generating periodic ramp waves, and

still another of said different circuits including a percussive sustain circuit connected between said single key operated switch and one of said keying gates.

30. The combination according to claim **29** wherein said single isolating gate is a solid-state switch having an output terminal, said solid-state switch presenting a leakage capacity C in series with said sources, and a capacitor of value nC shunting said output terminal to a reference level, where n is of the order of **100**.

31. The combination according to claim **29** wherein said single isolating gate is a solid-state diode having an output terminal, said solid-state diode having a leakage capacity C in series with said source and a capacitor of value nC shunting said output terminal to a reference level, where n is of the order of **100**.

32. The combination according to claim **29** wherein all said gates are solid-state gates.