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Woron

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[54] **WALSH FUNCTION TONE GENERATOR AND SYSTEM**

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[22] Filed: **Dec. 12, 1972**

[21] Appl. No.: **314,480**

[52] U.S. Cl. **84/1.01**; 84/1.01; 84/1.19; 84/DIG. 23; 235/197

[51] **Int. Cl.** **G10h 3/00**

[58] **Field of Search** .... 84/1.01, 1.11, 1.19, 1.04, 84/DIG. 23, DIG. 8, 1.21, 1.12, 1.23; 235/197; 179/15 BC, 1 SA

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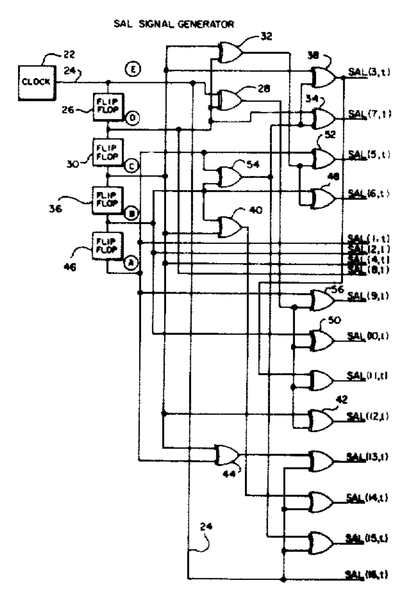
Primary Examiner—Richard B. Wilkinson
Assistant Examiner—U. Weldon
Attorney, Agent, or Firm—Seidel, Gonda & Goldhammer

[57] **ABSTRACT**

A Walsh function tone generator uses a summing means to sum a plurality of digital Walsh function signals to produce a tone output. The Walsh function generator may be comprised of a clock circuit, a plurality of frequency dividers for dividing the output of the clock circuit and a plurality of exclusive-OR gates for generating the various orders of the Walsh function signals. The summing means may include means for weighting the various orders of the Walsh function signals, such as weighting resistors. The Walsh function tone generator as used in an electronic musical instrument may be provided with bilateral electronic switches between the output of the Walsh function generator and the input of the summing means. The electronic switches may be used in conjunction with an attack and decay generator to provide an output wave form having the desired attack and decay characteristics.

The purpose of the above abstract is to provide a non-legal technical statement of the disclosure of the contents of the instant patent application and thus serve as a searching-scanning tool for scientists, engineers and researchers. Accordingly, this abstract is not intended to be used in understanding or otherwise comprehending the principles of the present invention hereinafter described in detail, nor is it intended to be used in interpreting or in any way limiting the scope or fair meaning of the claims appended hereto.

20 Claims, 10 Drawing Figures



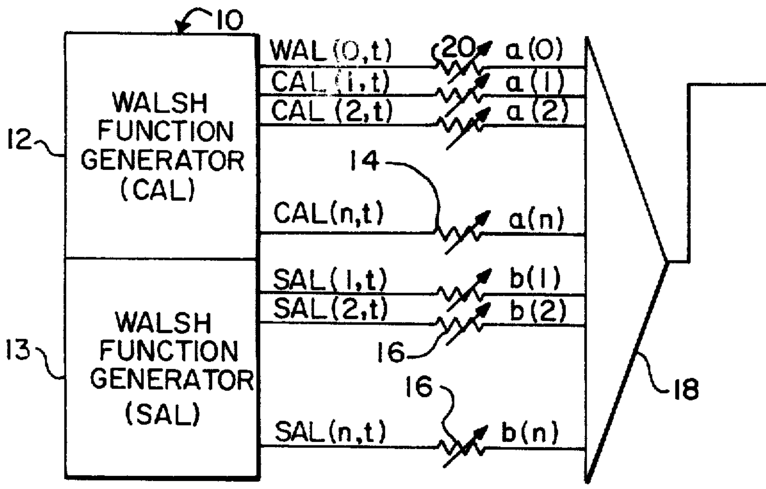


FIG. 1

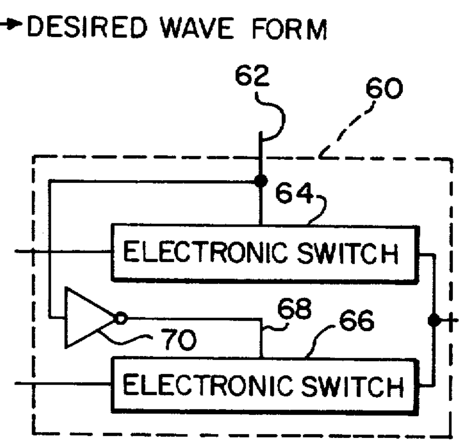


FIG. 5

SAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	A		A		A		A		A		A		A		A	
		B	B			B	B			B	B			B	B	
			C	C	C	C					C	C	C	C		
					D	D	D	D	D	D	D	D				
									E	E	E	E	E	E	E	E

FIG. 7

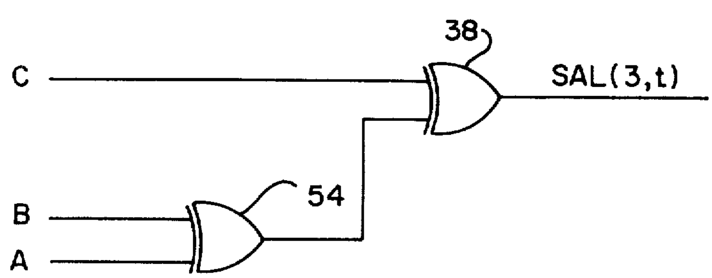
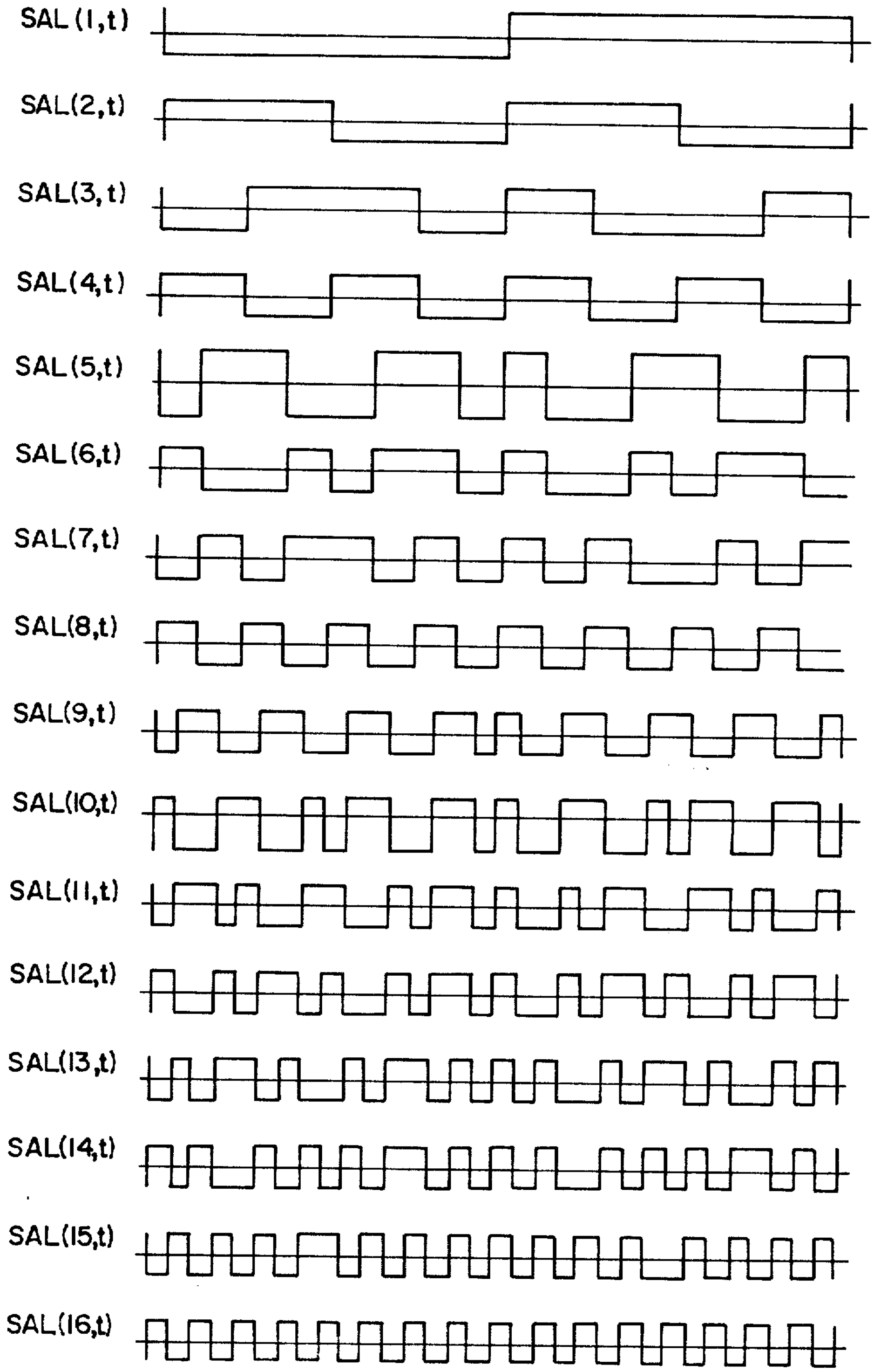


FIG. 6



FIRST SIXTEEN SAL SIGNALS

FIG. 2

SAL SIGNAL GENERATOR

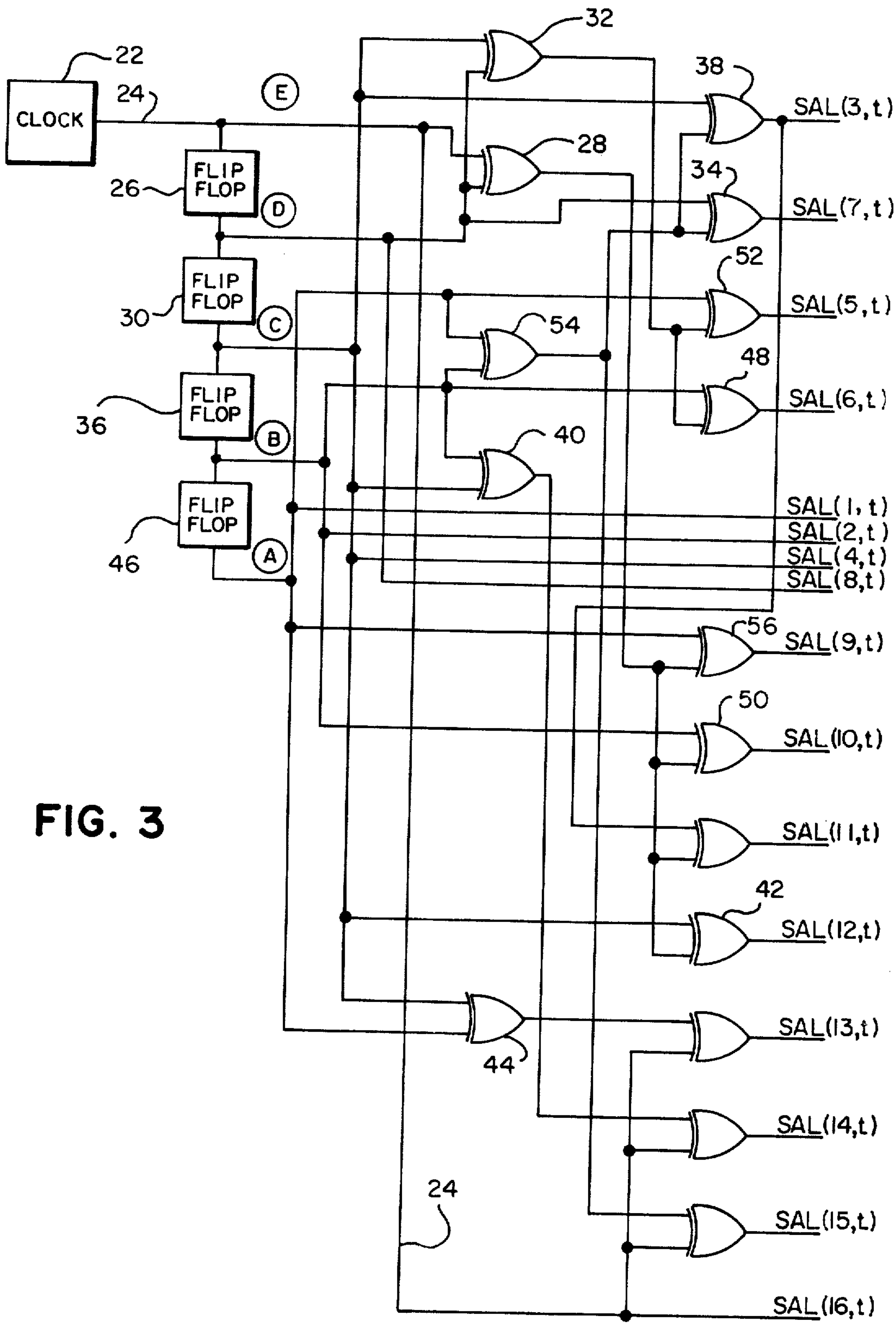


FIG. 3

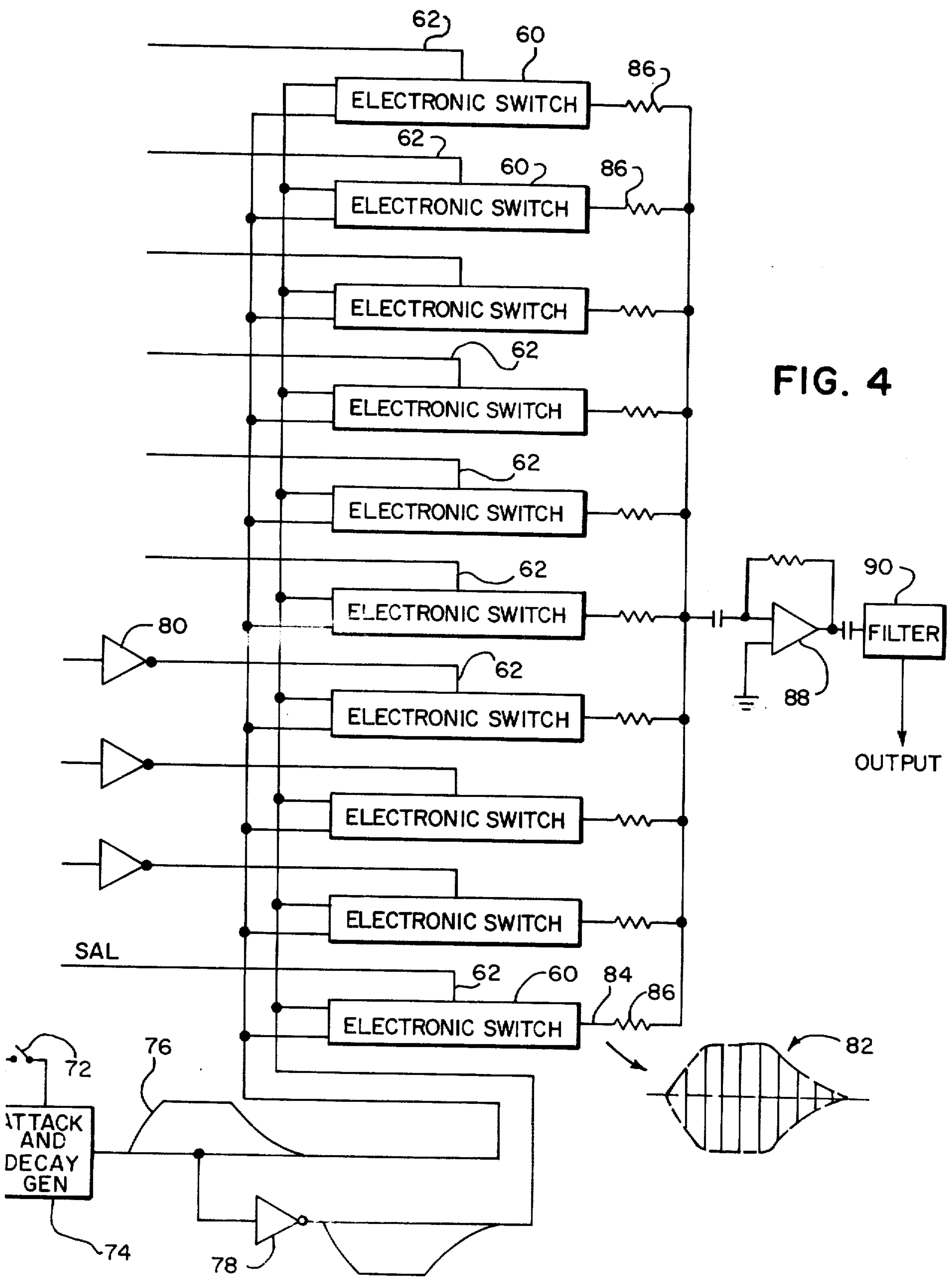

62
60
86
ELECTRONIC SWITCH
62
60
86
ELECTRONIC SWITCH
ELECTRONIC SWITCH
62
ELECTRONIC SWITCH
62
ELECTRONIC SWITCH
62
ELECTRONIC SWITCH
80
62
ELECTRONIC SWITCH
ELECTRONIC SWITCH
ELECTRONIC SWITCH
SAL
62
60
84
86
ELECTRONIC SWITCH
90
FILTER
88
OUTPUT
72
76
ATTACK AND DECAY GEN
74
78
82

FIG. 4

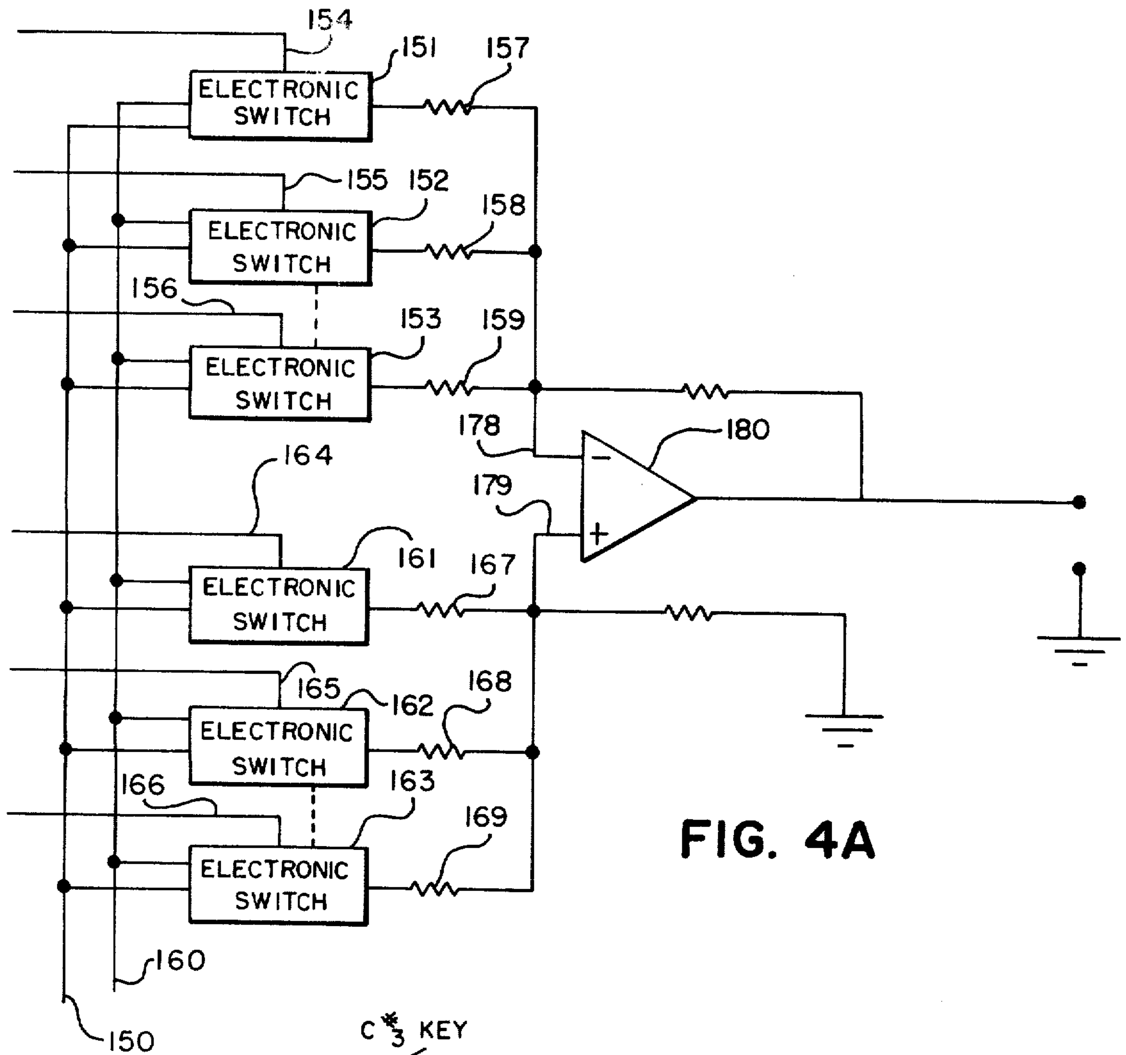

154
151
157
ELECTRONIC SWITCH
155
152
158
ELECTRONIC SWITCH
156
153
159
ELECTRONIC SWITCH
178
180
164
179
161
167
ELECTRONIC SWITCH
165
162
168
ELECTRONIC SWITCH
166
163
169
ELECTRONIC SWITCH
160
150

FIG. 4A

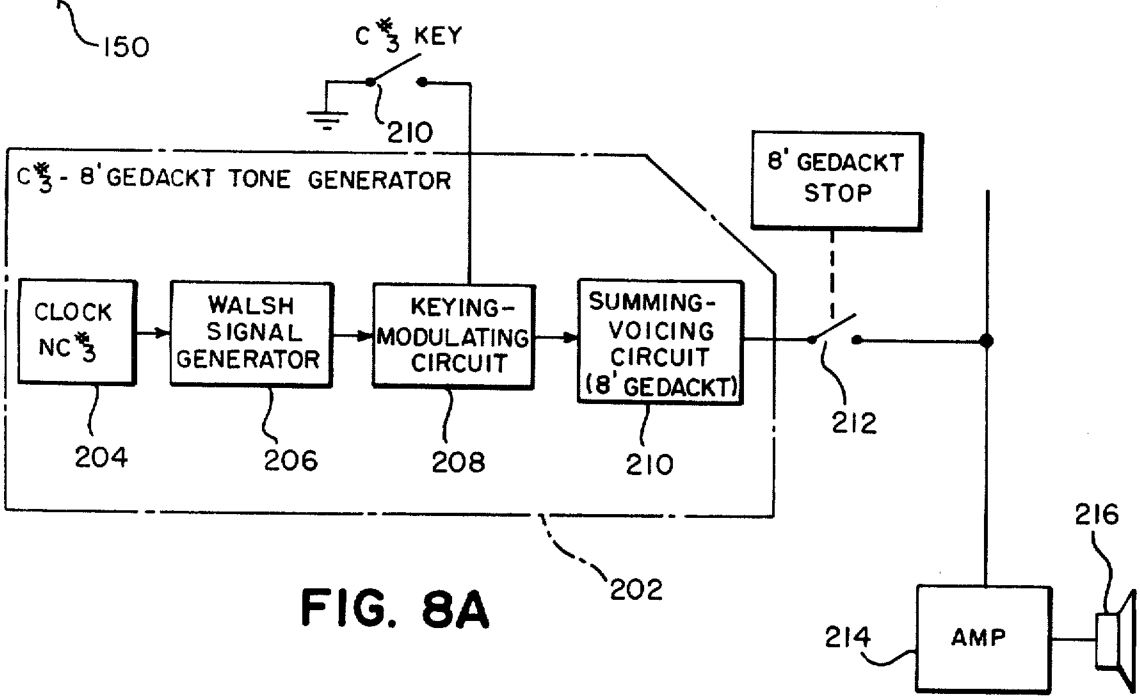

C#3 KEY
210
C#3 - 8' GEDACKT TONE GENERATOR
8' GEDACKT STOP
CLOCK NC#3
WALSH SIGNAL GENERATOR
KEYING-MODULATING CIRCUIT
SUMMING-VOICING CIRCUIT (8' GEDACKT)
204
206
208
210
212
202
216
214
AMP

FIG. 8A

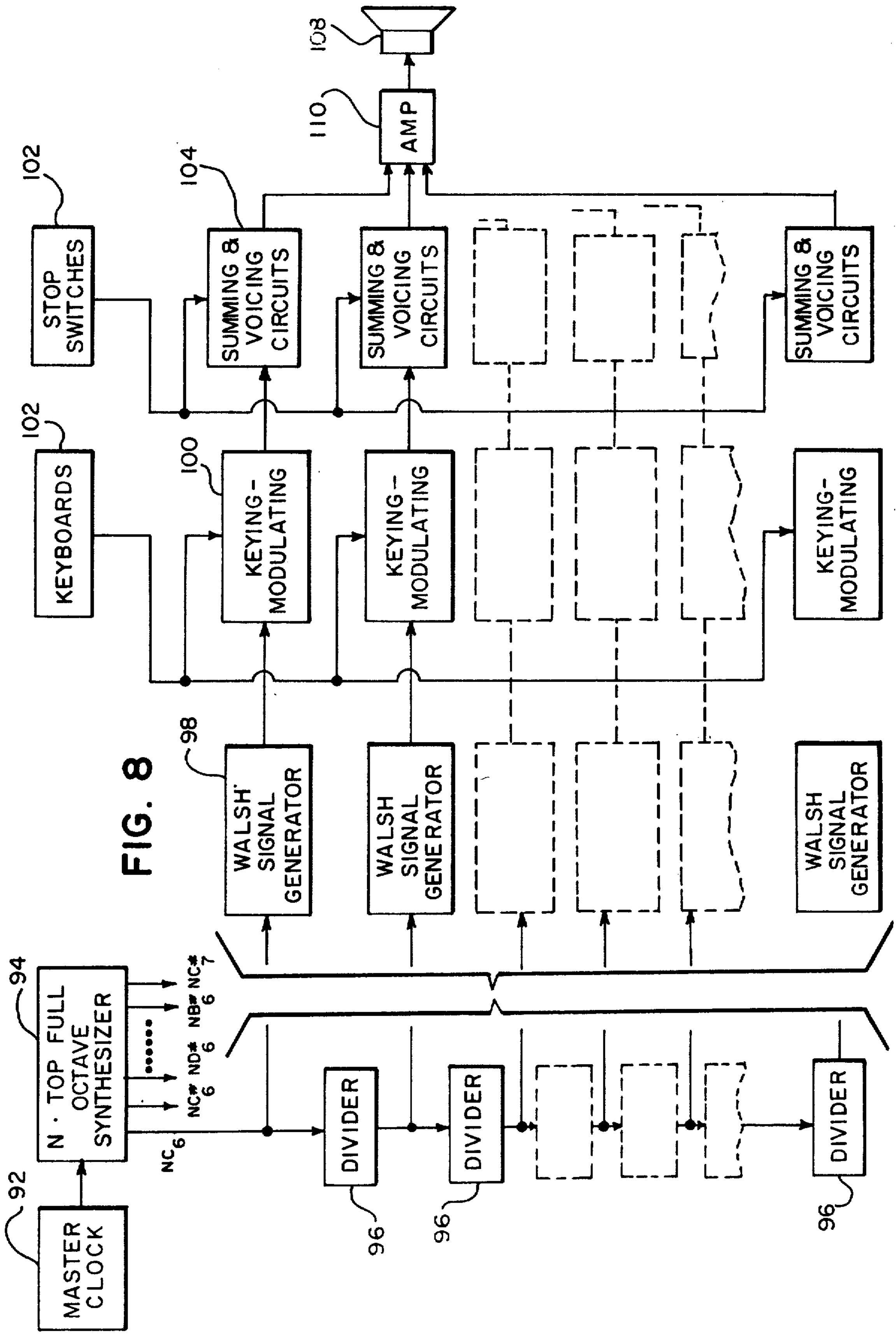

MASTER CLOCK
92
N · TOP FULL OCTAVE SYNTHESIZER
94
NC6
NC#6
ND#6
NB#6
NC#7
DIVIDER
96
WALSH SIGNAL GENERATOR
98
KEYING-MODULATING
100
KEYBOARDS
102
STOP SWITCHES
102
SUMMING & VOICING CIRCUITS
104
AMP
110
108

FIG. 8

WALSH FUNCTION TONE GENERATOR AND SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a Walsh function tone generator and system. More particularly, the present invention relates to a Walsh function tone generator in which predetermined Walsh functions are summed in order to generate a predetermined tone.

Heretofore tone generators and especially tone generators used in electronic musical instruments were built using capacitive and inductive elements based on the sine and cosine functions. The capacitive and inductive elements used in these tone generators were both bulky and expensive. This is especially true at the lower frequencies which are used in the production of music.

In accordance with the present invention, Walsh functions are used too synthesize complex wave shapes such as audio wave shapes. Walsh functions per se have been known for some time. For example, reference may be had to the following articles and others for a detailed mathematical discussion of Walsh functions: "A Closed Set of Orthogonal Functions," Am. J. Math., Vol. 55, pp. 5–24, 1923; "A Generalized Concept of Frequency and Some Applications," IEEE Transactions on Information Theory, Vol. IT–14, May, 1968 and "Applications of Walsh Functions in Communications," IEEE Spectrum, November, 1969.

The walsh functions form a complete, orthogonal system of functions. In this respect, they are similar to the complete, orthogonal system of functions formed by the sine and cosine functions. The Walsh functions are comprised of two functions which are known as the sal function and the cal function. The sal function is somewhat analogous to that of the sine function in that they are asymmetric or odd functions. The cal function and the cosine function are somewhat analogous in that they are symmetric or even functions.

The sal and cal functions of the Walsh function family may be of an unlimited number of orders. This is somewhat similar to the sine or cosine signals which may be of an unlimited number of different frequencies. The notation used herein is sal (**5**, *t*) or cal (**5**, *t*) wherein the "**5**" indicates the order of the sal or cal function and the "*t*" indicates that it is a function of time.

A significant advantage in the use of Walsh functions is that the Walsh functions are essentially binary. That is, the Walsh function signals have only two levels or conditions. The fact that a Walsh function may have only two conditions at any point other than a point of discontinuity is a significant advantage since it allows the use of modern digital integrated circuit technology to produce any desired complex wave form. The use of integrated circuit technology enables the generation of a large number of Walsh functions on a single integrated circuit chip.

SUMMARY OF THE INVENTION

The present invention provides a new and unobvious tone or wave form generation means which is particularly useful in electronic musical instruments. The term tone as used herein means any single frequency tone or any complex wave form. The present invention provides a significant advantage in that the tone may be generated by the use of digital electronic techniques

Briefly, in accordance with the present invention, there is provided an apparatus for producing a musical tone having means for generating a plurality of digital Walsh function signals and means for summing predetermined ones of the plurality of digital Walsh function signals in order to produce a tone output. Predetermined ones of the plurality of digital Walsh function signals may be weighted by predetermined amounts prior to summing if the desired tone so requires.

In accordance with a more detailed aspect of the invention, a digital Walsh function signal generator may be comprised of a clock circuit feeding a plurality of frequency dividers. The output of the clock circuit and the outputs of the frequency dividers are fed to a plurality of exclusive-OR logic circuits. The walsh function signals at the outputs of the exclusive-OR- logic circuity are fed to electronic switches. The digital Walsh function signals control the electronic switches gating an attack and decay modulated keying signal. The outputs of the electronic switches may be weighted by means of weighting resistors or other suitable means. The weighted Walsh function signals are then summed in a summing amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, there are shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIG. **1** is a schematic diagram in block diagram form of an apparatus in accordance with the present invention.

FIG. **2** is a drawing of wave forms generated in practicing the present invention.

FIGS. **3** and **4** are schematic diagrams, partially in block diagram form, of an embodiment of an apparatus in accordance with the present invention.

FIG. **4A** is a schematic diagram, partially in block diagram form, of another embodiment of the apparatus of FIG. **4** in accordance with the present invention.

FIG. **5** is a schematic diagram, partially in block diagram form, showing the electronic switches of FIG. **4** in greater detail.

FIG. **6** is a schematic diagram of exclusive-OR logic circuitry in accordance with the present invention.

FIG. **7** is a table illustrating one of the principles of the present invention.

FIG. **8** is a schematic diagram in block diagram form of an electronic musical instrument in accordance with the present invention.

FIG. **8A** is a schematic diagram in block diagram form of another embodiment of an electronic musical instrument in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in detail, wherein like numerals indicate like elements, there is shown in FIG. **1** a block diagram of a system in accordance with the present invention for producing any desired wave form. In order to produce any desired wave form with exactness, it is necessary to be capable of summing all of the cal and sal functions, with each weighted in a predetermined manner.

In FIG. **1**, there is shown a Walsh function generator **10** which includes a cal function generator **12** and a sal function generator 13. The cal function generator produces a cal function outputs cal (1, t). . . cal (n, t). The cal outputs are weighted by variable resistors 14 in order to provide the cal coefficients a (1) . . . a(n), respectively. The sal function generator 13 produces sal function output signals sal (1, t) . . . sal (n, t). Similarly, variable resistors 16 provide the desired weighting of the sal function output signals. The cal function signals, sal function signals and wal (O, t) function signal are summed in summing amplifier 18 to produce the desired wave form output depending upon the setting of the variable resistors 14, 16 and 20.

In general, both sal and cal signals are needed to synthesize an arbitrary wave shape. However, in the case of the generation of musical tones which are intended for perception by a human ear, certain optimizations may be made so that only sal signals, for example, may be required to synthesize the desired audio tones. It is known that the ear can perceive changes in amplitude of various harmonics in a musical tone. However, changes in the relative phasing of the harmonics in the audio sound create very little change in the perception of the sound by a human ear. Therefore, phasing of harmonics in the desired musical tone may be arranged in such a way as to optimize the synthesis. It has been found that arranging the phasing in the tone or sound so that each harmonic is in phase with the fundamental produces an audio wave shape which may be generated using only sal signals. In addition, Wal (o, t), the d.c. term is not needed. Therefore, the use of sal functions alone is sufficient to produce good quality audio tone or music. The wave forms of the first sixteen orders of sal signals are shown in FIG. 2.

As discussed above, the Walsh functions form a complete, orthogonal system of functions. The Walsh functions are adaptable to a Fourier type of analysis. In other words, Walsh-Fourier series expansions of functions in terms of the Walsh cal and sal functions have been defined in the literature and Walsh-Fourier transforms have been derived. Therefore, a significant advantage of using Walsh functions in the generation of tones is that methods exist for calculating the orders of sal or cal functions required and the amplitude of these functions, or in other words, the value of the weighting resistors for the particular cal or sal function.

Referring now to FIGS. 3 and 4, there is shown another embodiment of the present invention. In FIG. 3, there is shown a sal signal generator for generating the first sixteen sal signals as shown in FIG. 2. As shown in FIG. 3, a clock circuit 22 is provided. The output of clock circuit 22 is a pulse signal having a frequency or repetition rate which is a predetermined number of times the fundamental frequency of the tone being generated. As a specific example in FIG. 3, the output of the clock circuit would be sixteen times the fundamental frequency of the tone being generated.

The output of the clock circuit is fed via line 24 to flip-flop circuit 26, one input of exclusive-OR gate 28 and the output line labeled sal (16, t). That is, in the specific example being illustrated, the output of the clock circuit forms the sixteenth order sal signal. The clock signal on line 24 in FIG. 3 is labeled E.

The output of flip-flop circuit 26 is a pulse output signal having a frequency one-half of that of the clock circuit 22 output. The output signal of flip-flop circuit 26 is labeled D. The output signal D of flip-flop circuit 26 is fed to flip-flop 30, one input of exclusive-OR gate 28, one input of exclusive-OR gate 32, one input of exclusive-OR gate 34, and directly to the output labeled sal (8, t).

The output signal of flip-flop circuit 30 is labeled C. The C signal has a frequency one-fourth that of the output of clock circuit 22. The signal C is fed to flip-flop circuit 36, one input of exclusive-OR gate 32, one input of exclusive-OR gate 38, one input of exclusive-OR gate 40, one input of exclusive-OR gate 42, one input of exclusive-OR gate 44, and directly to the output line labeled sal (4, t).

The output signal of flip-flop circuit 36 is labeled B. The output signal B has a frequency or pulse repetition rate of one-eighth that of signal E which is the output of clock circuit 22. Signal B is fed to the input of flip-flop circuit 46. In addition, signal B is fed to one input of exclusive-OR gates 54, 40, 48 and 50 and directly to the output labeled sal (2, t).

The output of flip-flop circuit 46 is a signal A having a frequency of one-sixteenth that of signal E. The output signal A of flip-flop circuit 46 is fed to one input of exclusive-OR gates 52, 54, 56 and 44. In addition, signal A is fed directly to the output labeled sal (1, t).

There is shown in FIG. 7 a table for indicating which of the signals A, B, C, D and E are to be combined by modulo two addition in order to produce the various sal signals. As shown in FIG. 7, the top row indicates the order of the sal function. The letters in the various columns indicate that those signals must be combined by modulo two addition in order toi produce the particular order of sal function indicated at the top of the particular column. For example, the first order sal function is simply the signal A. The eleventh order sal function is produced by the modulo two addition of signals A, B, C, D and E. Similarly, the table in FIG. 7 indicates the derivation of all of the first sixteen orders of sal signals.

Referring now to FIG. 6 in conjunction with FIG. 3, there is shown the exclusive-OR circuitry for generating the third order sal signal. This circuitry is shown alone in FIG. 6 and in conjunction with the remaining exclusive-OR circuitry in FIG. 3. It may be seen that signals A and B are applied to exclusive-OR gate 54. An exclusive-OR gate, as is well known, produces a signal output when there is a signal present on one of its inputs but not both. Therefore, exclusive-OR gate 54 produces an output when either signal A or signal B is present, but not when both signals A and B are present. The output oif exclusive-OR gate 54 is fed as one input to exclusive-OR gate 38. Exclusive-OR gate 38 receives as its second input the signal C. Exclusive-OR gate 38 therefore produces an output when either one or three of the signals A, B and C are present. In a similar manner, the other orders of sal functions are generated by the occurrence of an odd number of signals indicated in the particular column in FIG. 7.

It is believed unnecessary to trace and discuss every line in FIG. 3 since the operation of the circuitry is apparent in view of the above discussion. However, the generation of the ninth order sal signal will also be traced out as an additional example of the operation of the circuitry shown in FIG. 3. Sal (9, t) is the output signal of exclusive-OR gate 56. Exclusive-OR gate 56 receives as one of its inputs signal A which is the output of flip-flop circuit 46. The other input of exclusive-OR gate 56 is received from the output of exclusive-OR gate 28. Exclusive-OR gate 28 receives signals D and E as its inputs. Therefore, the output signal sal (9, t) is the modulo two addition of signals A, D and E as indicated in FIG. 7.

The output sal signals of the sal signal generator shown in FIG. 3 may be fed directly to the summing means **18** as illustrated with respect to FIG. **1**. In the alternative, the output sal signals of the sal signal generator may be fed to an electronic switching network as shown in FIG. **4**. The electronic switching network shown in FIG. **4** provides a means of attack and decay modulating the tone to be produced. Selected ones, some or all, of the sal outputs generated by the circuitry shown in FIG. 3 will be applied to the gate electrodes of the electronic switches shown in FIG. 4.

The foregoing describes the generation of Walsh sal functions. Walsh function generators for generating cal functions or both cal and sal functions are known to those skilled in the art. See, for example, Lebert, "Walsh Function Generator for a Million Different Functions," Applications of Walsh functions Symposium and Workshop, 1970 Proceedings, United States Department of Commerce, pages 52–54.

Referring now in detail to FIG. **4** in conjunction with FIG. **5**, there is shown a plurality of electronic switch means **60** each having a control gate input line **62**. Electronic switch means **60** functions as a bilateral single pole double throw switch. Electronic switch means **60** is shown in greater detail in FIG. **5** wherein it is seen that each electronic switch means **60** includes a first electronic single pole single throw switch **64** and a second electronic single pole single throw switch **66**. The control gate input **68** of electronic switch **66** is provided with an inverter **70**. As a specific example of suitable hardware, electronic switch **60** may be a complementary-symmetry metal-oxide semiconductor of the type CD 4016A Quad Bilateral Switch manufactured by RCA. However, this specific example of hardware is not intended to be limiting and any other suitable electronic switch may be used in practicing the invention.

Referring back now to FIG. **4**, there is shown a key or key switch **72** which operatively controls attack and decay generator **74**. The output of attack and decay generator **74** is a wave form as shown at **76**. The wave form output of attack and decay generator **74** is applied to one of the inputs of each electronic switch means **60** directly and is applied to the other input of each of the electronic switch means **60** through analog inverter **78**.

The sal output signals from the sal signal generator shown in FIG. 3 are applied to the control gate input lines either directly or through digital inverters **80**. The presence or absence of an inverter is determined by whether the component sal function making up the tone is to have a positive or negative coefficient.

There is shown in FIG. **4** wave form **82** which is generated on line **84** for an attack and decay wave form **76** as shown at the output of attack and decay generator **74** and a sal signal on control gate input line **62**. As may be seen from wave form **82**, electronic switch means **60** effectively gates either the attack and decay wave form **76** or its inverse from analog inverter **78** in response to the sal signal appearing on control gate input line **62**.

The outputs of the electronic switch means **60** are fed through weighting resistors **86** to summing amplifier **88**. The output of summing amplifier **88** is fed to filter **90**. Filter **90** may be a low pass filter which eliminates any high frequency noise due to the digital nature of the sal signals. The output of filter **90** is the desired tone.

Referring now to FIG. **4A**, there is shown another embodiment of an electronic switching arrangement which does not require the use of inverters to produce the inverted coefficient. The embodiment shown in FIG. **4A** uses both inverting and non-inverting input terminals of an operational amplifier in order to produce an output corresponding to both positive and negative coefficients.

The attack and decay wave form is applied to each of the electronic switches **151–153** and **161–163** via line **150**. The inverted attack and decay wave form is applied to each of the electronic switches **151–153** and **161–163** via line **160**. The dotted lines between electronic switches **152** and **153** indicate that numerous other electronic switches may be used depending upon the tone to be produced. Similarly, the dotted lines between electronic switches **162** and **163** indicate that any desired number of electronic switches may be used to supply the non-inverting terminal of operational amplifier **180**.

Sal signals which are to have inverted coefficients would be applied to control gate input lines **154–156** of electronic switches **151–153**, respectively. Sal signals which would correspond to non-inverted signals in the output tone are applied to control gate input lines **164–166** of electronic switches **161–163**, respectively. The gated outputs of electronic switches **151–153** are applied to the inverting input **178** through their weighting resistors **157–159**, respectively. The gated outputs of electronic switches **161–163** are applied to the non-inverting input terminal **179** of operational amplifier **180** through weighting resistors **167–169**, respectively. As is well known, operational amplifier **180** will produce a signal appearing on non-inverting input **179** in amplified form and the signal appearing on inverting input **178** in an inverted and amplified form. The output of operational amplifier **180** is applied to a filter circuit (not shown) and used in a manner similar to the output of amplifier **88** in FIG. **4**.

Referring now to FIG. **8**, there is shown in block diagram form an electronic musical instrument such as an electronic organ. There is shown a master clock **92** which produces a pulse output having a frequency which is N times the highest note frequency to be produced. The output of master clock **92** is fed to a top octave synthesizer **94**. Top octave synthesizers are well-known in the art, commercially available and need not be described herein in detail. Top octave synthesizer **94** produces frequency output signals having frequencies of N times the frequencies of the notes C_6, C_6 #, D_6, . . B_6 and C_7. In an embodiment as described with respect to FIGS. **3** and **4**, N would equal **16**. However, N may equal any suitable number sufficient to give the desired degree of accuracy. That is, as N increases, the accuracy of the tone produced also increases.

The output of top octave synthesizer **94** which is labeled NC_6 is fed to cascaded frequency dividers **96**. The other outputs of top octave synthesizer **94** would be fed to similar sets of cascaded dividers.

The outputs of the dividers **96** are fed to Walsh signal generators **98**. The outputs of the Walsh signal generators are fed to keying-modulating networks **100**. The keying-modulating networks **100** receive an input from keyboard **102**. The keying-modulating networks **100** perform the function as described with respect to FIG. 4.

The outputs of the keying-modulating networks **100** are fed to summing-voicing circuits **104**. The summing-voicing circuits **104** receive an input from the stop switches **106** which determine the voice of the tone to be produced (that is, the combination of weighting resistors **86**). The outputs of the summing-voicing circuits are applied to speaker **108** through amplifier **110**.

Referring now to FIG. **8A**, there is disclosed another embodiment of a musical instrument in accordance with the present invention. In the embodiment shown in FIG. **8A**, a top octave synthesizer is not required. In accordance with the embodiment of FIG. **8A**, a complete tone generator is used for each key-stop combination. A C_3 # -8 foot Gedackt tone generator is shown at **202** in FIG. **8A**. Additional stops playing a C_3 # note would be provided by additional tone generators tuned and voiced accordingly. The embodiment shown in FIG. **8A** has the musical advantage that the various notes are independent or in other words are not phase locked.

Referring now more particularly to FIG. **8A**, there is shown a clock **204** which provides a frequency at N times the C_3 # note frequency. The output of clock circuit **204** is fed to Walsh signal generator **206**. The output of Walsh signal generator **206** is fed to keying-modulating circuit **208**. Keying-modulating circuit **208** receives an input from the C_3 # key or key switch **210**. The output of keying-modulating circuit **208** is fed to summing-voicing circuit **210**. The output of summing-voicing circuit **210** is fed through the **8** foot Gedackt stop switch **212** to amplifier **214**. Amplifier **214** also receives output signals from the other tone generators (not shown) in the musical instrument. The output of amplifier **214** is fed to speaker **216**. Speaker **216** converts the amplified electrical signals into musical sound waves.

It will be apparent to those skilled in the art that various changes and modifications may be made within the spirit of the above teachings. For example, although the operation has been disclosed in detail with respect to sal functions, it is apparent that cal functions could be used as well. Various other types of logic may be used to generate the Walsh functions and various other keying and switching techniques may be used. Furthermore, the illustration of two embodiments of electronic musical instruments are only selected examples, and it is apparent that many variations may be made within the spirit of the present invention.

In view of the above, the present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. Apparatus for producing a musical tone, comprising:

clock means for generating a clock signal at a frequency which is a predetermined number times the fundamental frequency of the musical tone to be generated;

means for receiving a clock signal and for generating a plurality of digital Walsh function signals; and

means for summing predetermined ones of the plurality of digital Walsh function signals to produce a musical tone output.

2. Apparatus in accordance with claim **1** including means for weighting predetermined ones of said digital Walsh functions by predetermined amounts, said weighting means being connected between said digital walsh function generating means and said summing means.

3. Apparatus in accordance with claim **1** wherein said digital Walsh function signal generating means includes means for generating a predetermined number of orders of cal function signals.

4. Apparatus in accordance with claim **1** wherein said digital Walsh function signal generating means includes means for generating a predetermined number of orders of sal function signals.

5. Apparatus in accordance with claim **1** wherein said digital Walsh function signal generating means includes means for generating a first predetermined number of cal function signals and a second predetermined number of sal function signals.

6. Apparatus for producing a musical tone, comprising:

a clock circuit;

a predetermined number of frequency dividers, said frequency dividers producing submultiples of the clock frequency output of said clock circuit;

gating means for producing output signals in response to predetermined combinations of input signals from said clock circuit output and said frequency divider outputs to generate a predetermined number of orders of Walsh function signals;

means for generating a modulating envelope for modulating the Walsh function signals;

a predetermined number of electronic switch means, said electronic switch means receiving said modulating envelope, said electronic switch means gating the modulating envelope in response to predetermined ones of the output Walsh function signals of said gating means; and

summing means, said summing means summing the gated outputs of said electronic switch means.

7. Apparatus in accordance with claim **6** including means for weighting the gated outputs of said electronic switch means.

8. Apparatus in accordance with claim **6** wherein said frequency dividers are flip-flops.

9. Apparatus in accordance with claim **6** wherein said gating means is comprised of exclusive-OR gates.

10. Apparatus in accordance with claim **6** wherein said electronic switch means receive the modulating envelope from an attack and decay generator, said attack and decay generator receiving a signal input from a key switch.

11. Apparatus in accordance with claim **9** wherein each of said electronic switch means is comprised of a first and a second electronic switch, said first and second electronic switches each being provided with an input, an output and gate terminal, the modulating envelope being applied to the input terminals of each of said first and second electronic switches, a predetermined Walsh function signal being applied to said gate terminal of said first electronic switch and said gate terminal of said second electronic switch through an inverter circuit.

12. Apparatus in accordance with claim **6** wherein said gating means produces sal signals.

13. Apparatus in accordance with claim **6** including inverters for inverting predetermined ones of the Walsh function signal outputs of said gating means.

14. Apparatus in accordance with claim **6** wherein said summing means includes an operational amplifier provided with a non-inverting input terminal and an inverting input terminal, predetermined ones of the gated outputs of said electronic switch means being applied to said non-inverting input terminal and other predetermined ones of the gated outputs of said electronic switch means being applied to said inverting input terminal.

15. An electronic musical instrument, comprising:

a clock circuit;

a top octave synthesizer, said top octave synthesizer receiving the output of said clock circuit and generating a predetermined number of frequency signal outputs having frequencies equal to N times the top octave frequencies;

a predetermined number of sets of frequency dividers, one set of frequency dividers being provided for each top octave frequency signal output, each set of frequency dividers being provided with a predetermined number of frequency dividers;

a predetermined number of Walsh function generators for generating Walsh function signals in response to predetermined combinations of the top octave frequency signal output and the outputs of the frequency dividers in a set;

means for generating a modulating envelope for modulating the Walsh function signals;

means for combining the modulating envelope with the Walsh function signals;

means for summing the modulated Walsh function signals; and

means for transducing the summed Walsh function signals into sound waves.

16. An electronic musical instrument in accordance with claim **15** wherein said generating means generates a modulating signal to provide a desired attack and/or decay keying signal.

17. Apparatus in accordance with claim **15** including means for voicing the output of said summing means.

18. An electronic musical instrument, comprising:

a plurality of tone generators, each of said plurality of tone generators providing a predetermined tone output in response to being keyed, each of said plurality of tone generators being provided with a clock circuit, a Walsh tone generator, a keying-modulating circuit and a summing circuit means, said clock circuit producing an output having a frequency equal to a predetermined number of times the basic tone frequency output of the tone generator, said Walsh signal generator receiving the output of said clock circuit, said keying-modulating circuit receiving an input from a key corresponding to the particular generator and the output of said Walsh signal generator, the output of the keying-modulating circuit being applied to a summing circuit means, said summing circuit means producing a predetermined tone output;

amplifier means, said amplifier means receiving the tone output of each of said plurality of tone generators; and

transducer means for converting the electrical output of said amplifier to a sound wave.

19. An electronic musical instrument in accordance with claim **18** wherein said summing circuit means includes a voicing means.

20. Apparatus for producing a musical tone, comprising:

clock means for generating a clock signal at a frequency which is a predetermined number times the fundamental frequency of the musical tone to be generated;

means for receiving the clock signal and for generating a plurality of digital Walsh function signals;

weighting means for weighting predetermined ones of said Walsh function signals by predetermined amounts; and

means for summing predetermines ones of the plurality of weighted digital Walsh function signals to produce a musical tone output.

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