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Arsem et al.

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[54] DIGITAL ORGAN SYSTEM

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[51] Int. Cl. G10h 5/00
[58] Field of Search.....84/1.03, 1.17, 1.01, 1.11, 84/1.19, 122, 1.24

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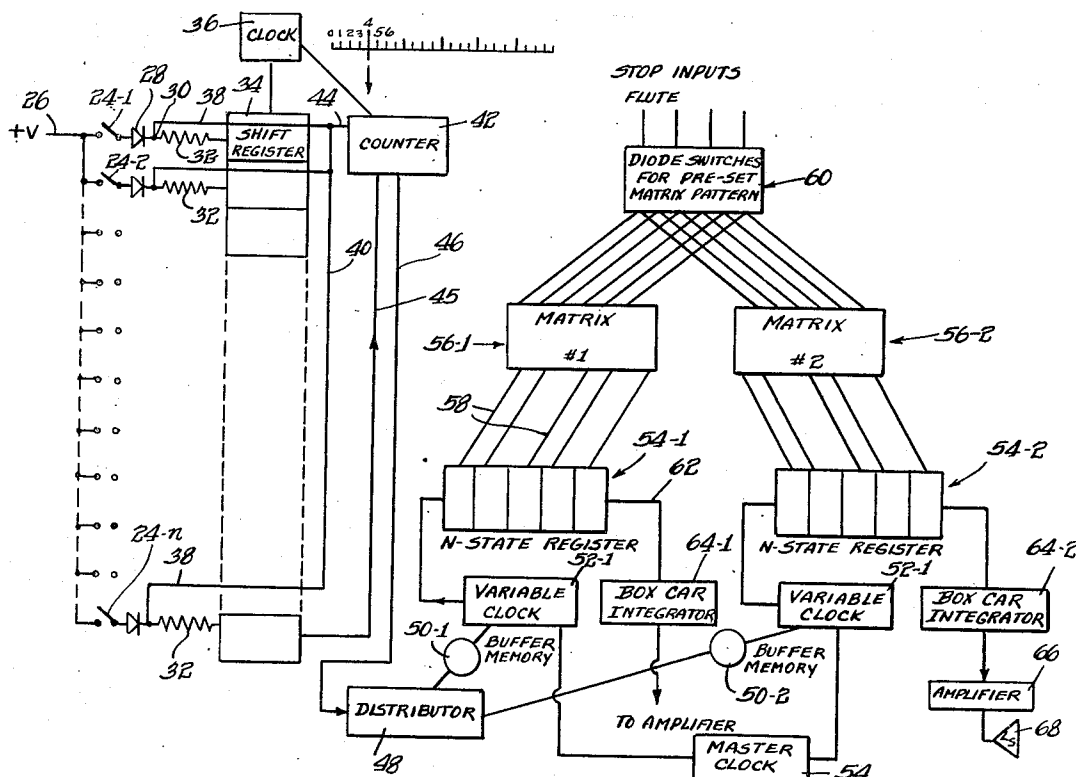
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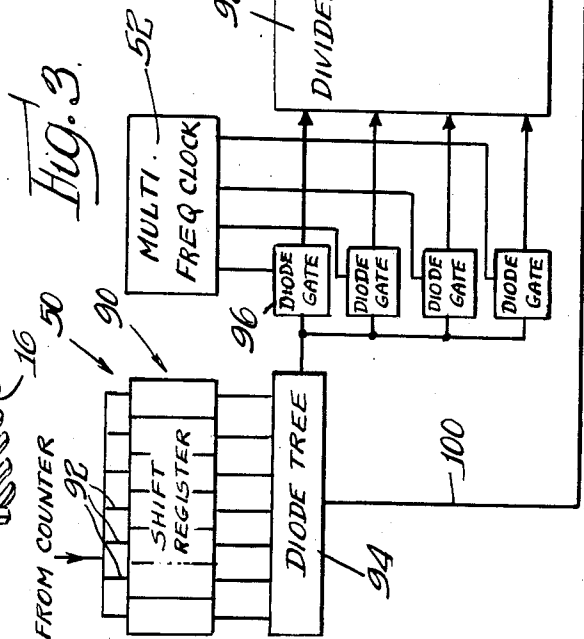
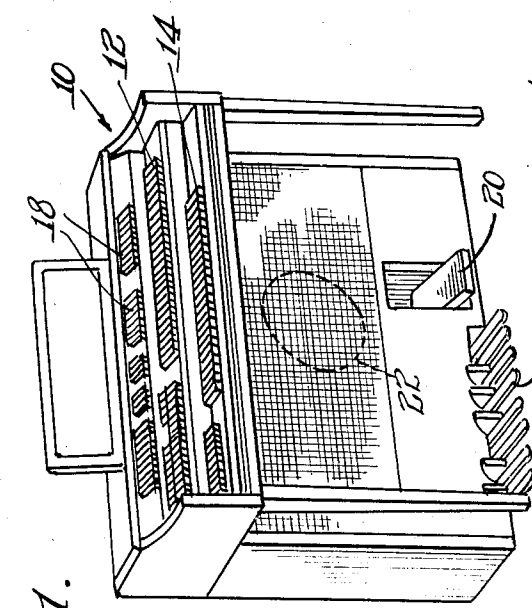
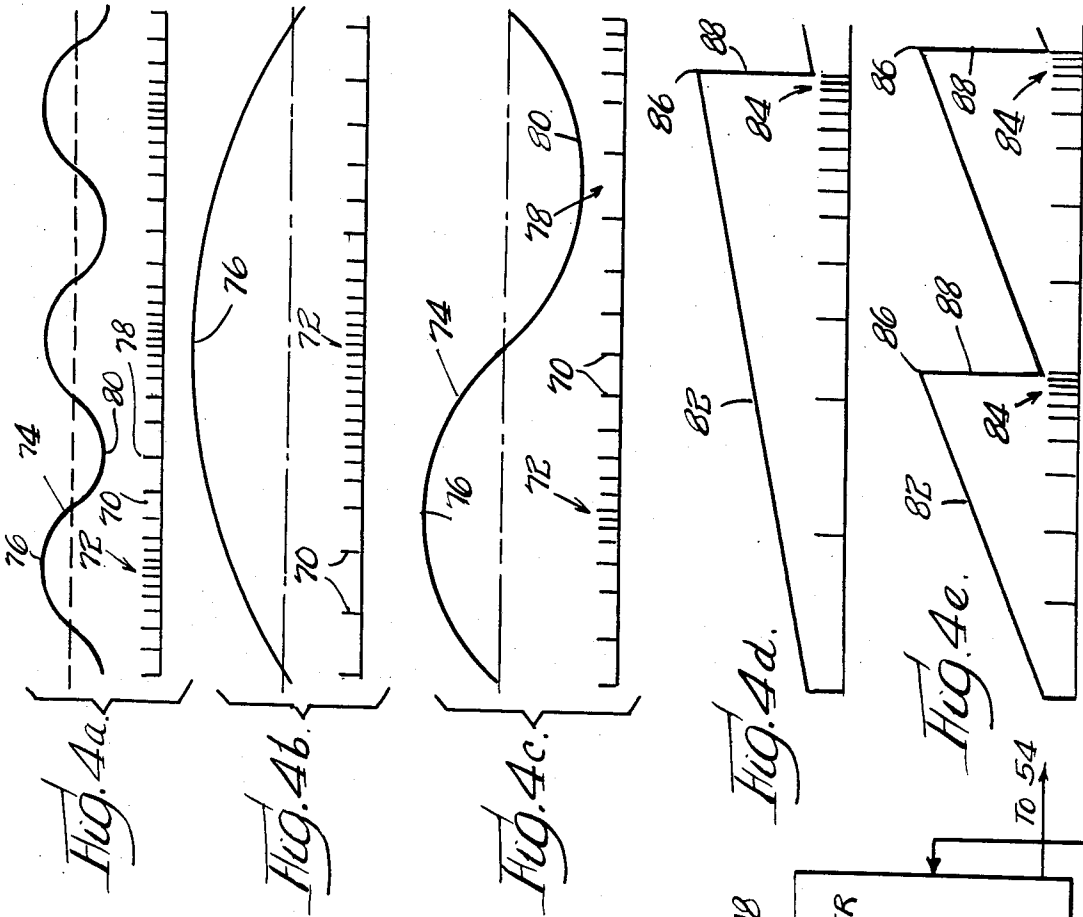
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[57] ABSTRACT

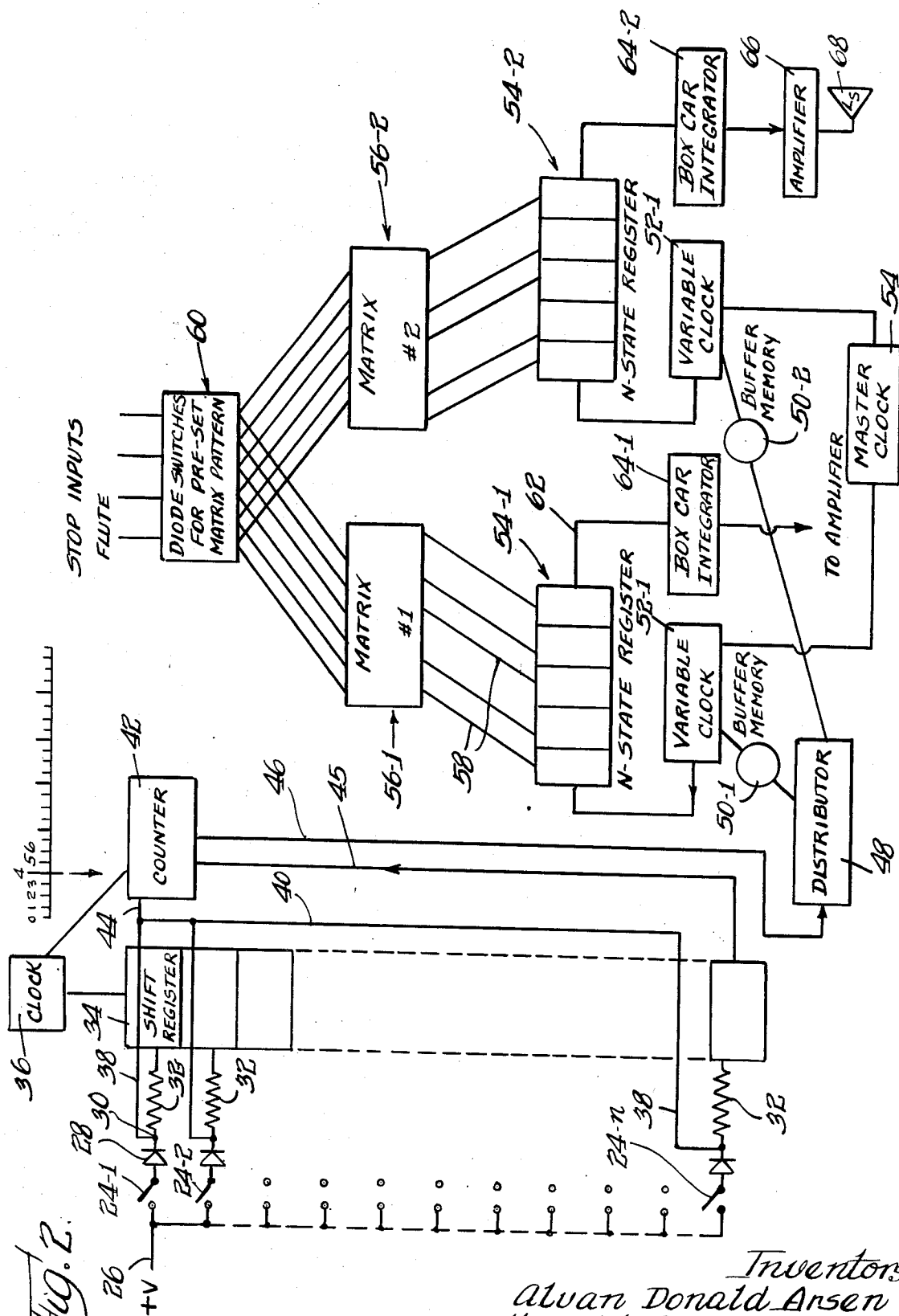
An electronic keyboard musical instrument, specifically an organ, in which the position of one or more keys depressed is indicated by a corresponding one or more binary numbers, which in turn respectively control variable clocks. The outputs of the variable clocks are applied to shift registers the outputs of which are applied to boxcar integrators to provide audio frequency outputs.

33 Claims, 11 Drawing Figures

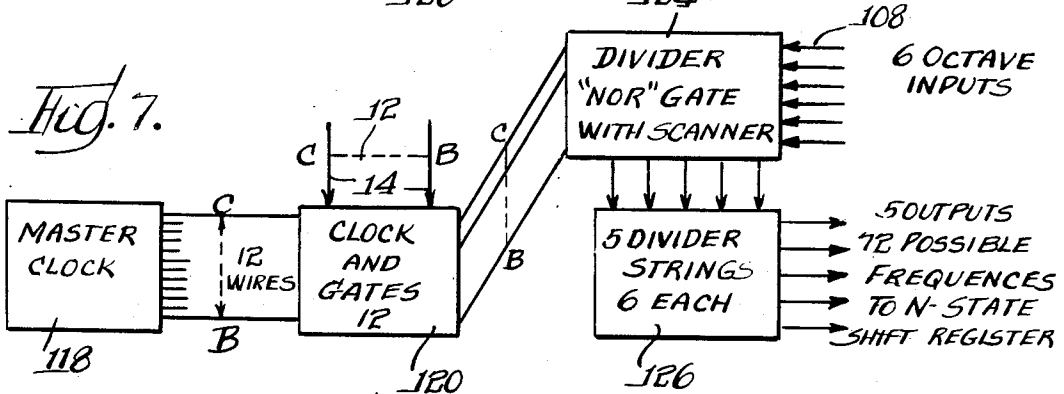
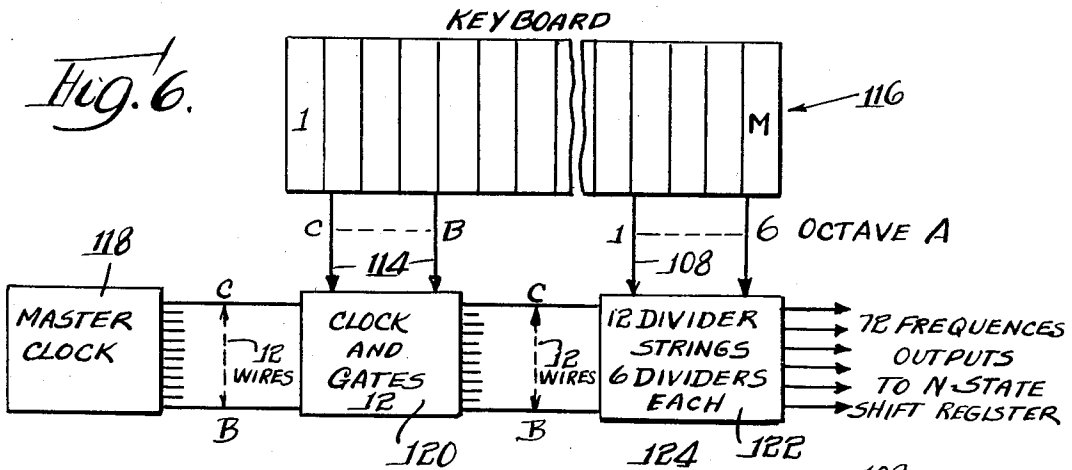
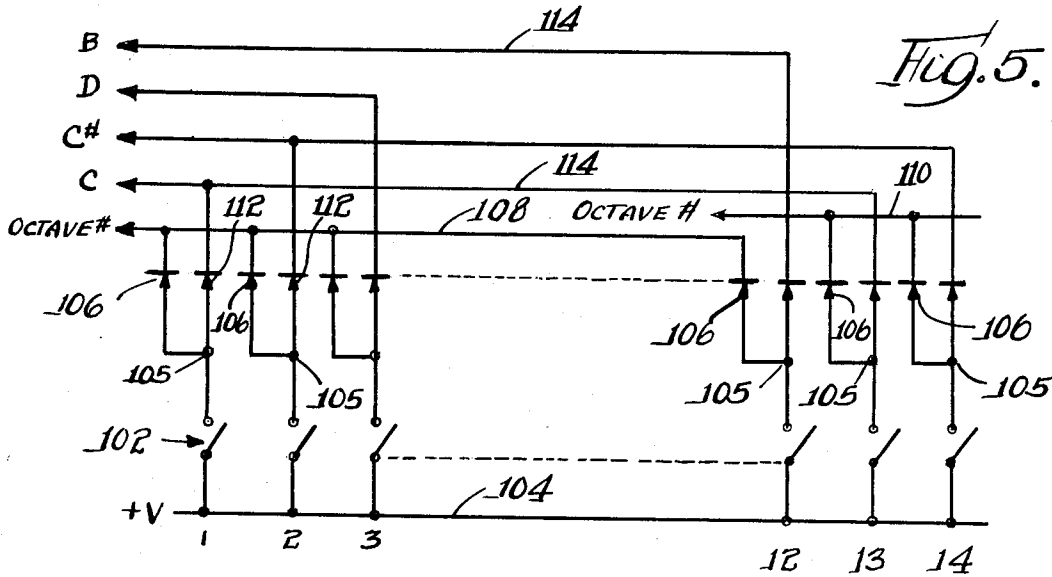




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DIGITAL ORGAN SYSTEM

Electronic organs have become relatively common. Such organs differ substantially in certain specifics, such as whether the tone generators used are additive or subtractive. They also differ as to the specific type of generator, i.e., transistor or tube oscillator, wind-driven reed, rotating tone wheel, etc. However, all commercial electronic organs to date have been distinguished by certain common features. In particular, every organ has a plurality of tone generators. Typically, there is one tone generator for each note of the two manuals commonly provided, and, in the case of the more sophisticated organs, there is also one tone generator for each pedal of the organ. In less sophisticated organs, the pedal tones are provided by one or more dividers which divide a frequency from the keyboard, and only one pedal note at a time can be played. It will be immediately apparent that there is a rather significant redundancy of tone generators, since the maximum number of notes that normally can be played at any one time is twelve, one for each finger, and one for each foot. In popular organ playing, it is unusual to use more than one pedal tone at a time, and it is more to be expected that perhaps five notes will be played by the fingers than that ten will. Some effort has been made to reduce redundancy by using tunable oscillators, wherein an oscillator is shared by two or three adjacent notes on the presumption that only one of such notes will be played at any one time. This presumption does not always hold true, and this is at best merely a temporizing action, since the number of generators provided is much greater than the number that can be played at any one time.

In any event, each oscillator or other tone generator provides an audio frequency oscillation that bears a direct relation to the frequency of the note being played. In the case of subtractive organs, the note generated is the fundamental of the note played. A large number of harmonics is provided by the generator (often by generating square waves), and the undesired harmonics are filtered out in accordance with the organ stop being played. In the case of additive organs, sine is common to provide a sine wave generator for each note corresponding to the fundamental frequency of the note, and to provide a large number of additional related generators for supplying harmonics. Even though the number of harmonics is so severely restricted as to produce tones which are not truly organ tones, it will be immediately apparent that the number of generators is proliferated rather than reduced.

It is an object of the present invention greatly to reduce or to eliminate redundancy in electric organs or other electronic keyboard instruments.

It is further an object of the present invention to effect the generator of each note played by means of a variable clock, and means for controlling the density of clock pulses to synthesize a desired audio waveform.

More specifically, it is an object of the present invention to provide an electronic organ wherein the output of one or more clocks is applied to a corresponding one or more shift registers having controlled paths to eliminate certain of the pulses, and thus to provide a synthetic audio wave generated by the pulse density.

It is further an object of the present invention to generate audio tones in an electronic organ by means

of a clock feeding a shift register having a matrix with a variable matrix pattern to control the density of pulses from the shift register, which pulses are applied to a boxcar integrator to produce the desired audio wave.

In accordance with the present invention, a shift register is provided having the same number of stages as the total number of key switches to an organ manual or pedal clavier. (Alternatively, the shift register could have a number of stages equal to the total number of key switches in all of the manuals and pedal claviers, thereby avoiding the necessity of having a separate shift register for each keyboard and pedal clavier). The shift register is connected to a counter which is in turn connected to a distributor, and thence to a succession of buffer memories. Whenever a key switch is closed, the corresponding shift register stage (the shift register being driven by a clock) provides an output to the counter, which then dumps the count to the buffer memories in sequence. Each buffer memory controls a like circuit including a variable clock connected to a shift register. Each shift register has a matrix, with the matrix adjustable in accordance with the wave shape desired. The output of this shift register is connected to a boxcar integrator, and the density of pulses from the shift register determines the audio wave from the boxcar integrator.

The foregoing, as well as other objects and advantages of the present invention, will be understood from a study of the following description when taken in connection with the accompanying drawings, wherein:

FIG. 1 is a perspective view of an organ constructed in accordance with the principles of the present invention;

FIG. 2 is a circuit diagram of a digital organ system in accordance with the present invention;

FIG. 3 is a more detailed wiring diagram of a portion of the diagram of FIG. 2;

FIGS. 4a-4c illustrate the correlation of pulse density and audio wave shapes for sine waves;

FIGS. 4d and 4e show the correlation of pulse density for illustrative sawtooth waves;

FIG. 5 is a schematic wiring diagram which illustrates one keyswitch arrangement in accordance with the present invention;

FIG. 6 is a schematic wiring diagram illustrating the principles of the present invention as applied to a redundant organ wherein there is a separate divider for each note of the organ; and

FIG. 7 is a schematic wiring diagram somewhat similar to FIG. 6 but wherein redundancy has been minimized.

Turning now to the drawings in greater particularity, and first to FIG. 1, there will be seen an electronic organ designated generally by the number 10. The organ illustrated is of the so-called spinet type, with two keyboards 12 and 14 of the somewhat shortened (i.e. 44 notes) and overlapping type, and with a pedal clavier 16 having 13 pedals, i.e., one octave plus one. The organ also is provided with a plurality of stop tablets 18, and with a swell pedal 20 for controlling the overall volume of the instrument. An amplifier of any suitable type is provided within the organ, and feeds a loudspeaker system behind a grille 22.

Turning now to FIG. 2, there is provided a plurality of key switches 24, one for each key or pedal of the or-

gan. Thus, in accordance with the organ illustrated in FIG. 1, there would be 101 key switches. The least redundancy in the organ occurs when all of the key switches are connected as illustrated in FIG. 2. However, it is frequently advantageous to duplicate the circuit of FIG. 2 for the upper and lower manuals 10 and 12, respectively, and possibly also for the pedal clavier 16 to permit channeling of the different keyboards, and also to permit the playing of different stops on the different keyboards. Thus, it will be understood that the present invention includes either expedient.

Each of the key switches 24 is normally open, and is provided on its input side with a positive voltage from a bus 26. On the output side, each of the key switches 24 is connected to the anode of a diode 28, the cathode being connected to the junction point 30. Each junction point is connected through a respective resistor 32 to one stage of a shift register 34. The shift register has a plurality of stages equal in number to the number of key switches 24, and the shift register is fed from a master clock 36.

Each stage of the shift register 34 is connected by a line 38 to a collector or bus 40, the collector 40 being connected to a counter 42 by a line 44. The shift register also is connected to the counter by a line 45. Due to control of the counter 42 by the same clock 36 as the shift register, the counter counts in synchronism with the shifting of the shift register. Whenever a key switch 24 is closed and the shift register shifts to the stage to which that key switch is connected, there is an output from that stage of the shift register which causes the counter 42 to dump its count onto an output line 46. The clock pulses into the counter are indicated against a time base immediately above the counter 42, and the arrow at pulse 4 indicates that, for example, the fourth of the switches 24 is closed, so that the counter 42 dumps the count at pulse 4 onto line 46.

Output line 46 is connected to a distributor 48, and distributor 48 is connected to a succession of buffer memories 50. The number of buffer memories is dependent on the amount of redundancy necessary. For example, if the circuit of FIG. 2 is considered as limited to a single manual, not more than five notes would be played at any one time, and there would be five buffer memories. On the other hand, if both manuals and the pedal clavier were included among the switches 24, then there would be a total possible of 12 notes, and there would be twelve buffer memories 50 provided. For purposes of distinction amongst the various buffer memories, a suffix is provided, i.e., buffer memory 50-1, buffer memory 50-2, etc. The key switches have likewise had suffixes applied to the numeral 24 to distinguish among the various key switches.

Each buffer memory 50 is connected to a variable clock 52, and the variable clocks are controlled by a master clock 54. This master clock 54 is synchronized with the clock 36, or it may be the same clock. The output of each variable clock is connected to a N-state shift register 54. Each of the shift registers 54 is connected to a matrix 56, the various stages being individually connected to the matrix by the lines indicated at 58. The patterns of the matrixes are all controlled by one set of diode switches 60 (or one set per manual and for the clavier when it is desired to play different stops on the different manuals, as is the usual

case). Provision is made for controlling the diode switches 60 in accordance with the type of voicing desired; for example, flute, etc. For example, the diode switches to preset the matrix pattern may be a plurality of photosensitive diodes, and a punch card having holes therein in accordance with the desired pattern is placed over the diodes. A light shining through the holes determines which of the photosensitive diodes will be conductive, whereby the card controls the pattern.

Due to the pattern, certain of the pulses fed into the shift register 54 by the respective variable clock will be missing from the output. Although the pulses missing depend directly on the matrix pattern, there is no simple relationship between the pattern and the presence and absence of output pulses.

In any event, the output pulses appear on the line 62 leading to a boxcar integrator 64. The boxcar integrator output is an audio frequency, with the waveform thereof depending on the density of output pulses from the shift register 54. The density is determined by the number of missing pulses. The frequency is determined in part by the variable clock 52, but it also may be determined at least in part by the density of pulses, since the matrix pattern can be arranged to provide a repeating pulse density pattern within any one cycle of the frequency applied to the shift register by the variable clock.

The output of each boxcar integrator 64 is applied to an amplifier 66, and the output of the amplifier—the intensity of which is controlled by the swell pedal 20—is applied to the loudspeaker 68 disposed behind the grille cloth 22. As will be understood, the loudspeaker 68 can be a complex group of loudspeakers, or a single loudspeaker.

The development of wave shapes from the boxcar integrator 64 is illustrated in FIG. 4. In the various sub-figures of FIG. 4, it is not intended to provide a precise representation, but rather one which is illustrative. Thus, referring first to FIG. 4a, wherever the pulses 70 bunch up, as at 72, the output wave 74 reaches a maximum as indicated at 76. Conversely, where the output pulses are spread out the most, as indicated at 78, the output wave has a minimum as indicated at 80. Intermediate spaced pulses produce an intermediate amplitude of output wave. As will be understood, the result as illustrated in FIG. 4a is a sine wave, specifically for a 4-foot pitch.

The development of an 8-foot sine wave is illustrated in FIG. 4c. Again, where the pulses bunch up at 72, there is a maximum amplitude of the output wave 74 as indicated at 76, and where the pulses are the most spread out, as at 78, there is a minimum amplitude of the output wave as indicated at 80.

Similarly, in FIG. 4b there is shown the development of a 16-foot sine wave, bunching up of pulses 70 at 72 again producing a maximum value of the output wave as indicated at 76. The maximum spreading out of the pulses to produce the minimum value is not illustrated in FIG. 4c, since only a half cycle of the output sine wave is shown in this figure.

The number of pulses is determined by the frequency of the variable speed clock 52 (and hence of the master clock 54), and also by the number of stages of a shift register 52. The more stages of the shift register and the higher the frequency of the clock, the greater the

resolution of the output wave from the boxcar integrator. As has been indicated heretofore, the pattern within a cycle of the variable speed clock can be controlled by the matrix pattern, and hence there can be one or more repeating cycles for each cycle of the clock, whereby the frequency may depend on the matrix pattern and the number of stages of the shift register, as well as on the frequency of the clock. It might be well to mention at this point that the minimum frequency from the variable clock is on the order of 7.5 kilocycles. However, better results are obtained, particularly with respect to fineness of detail, with operation at a higher frequency, such as on the order of 100 to 120 kilocycles per second.

With a proper matrix pattern, the pulses can be made to bunch up in the manner shown in FIG. 4d, to provide a sawtooth output wave 82, the maximum density of pulses occurring at 84 immediately below the maximum height of the sawtooth wave at 86, and the greatest spacing being immediately after the drop-off or retrace 88. An 8-foot sawtooth wave is illustrated in FIG. 4d, and the development of a 4-foot sawtooth wave is shown in FIG. 4e.

The buffer memory 50 referred to in connection with FIG. 2 is shown in somewhat greater detail in FIG. 3, and includes a shift register 90 with the output from the counter 42 (through the distributor 48) being applied thereto in parallel through the various leads 92. The outputs of the various stages of the shift register 90 are connected to a diode tree 94, and the output of the diode tree is connected to a plurality of parallel diode gates leading to a divider 98. A line 100 leads from the diode tree to the divider 98 to enable various division ratios of from 1 through 5. The variable or multi-speed clock 52 is also connected to the various diode gates 96 to provide the input into the divider. The output from the divider goes to the N-state shift register 54.

Some of the foregoing principles can be utilized with somewhat greater simplicity as illustrated in FIGS. 5-7. As will be appreciated, it is necessary to obtain two pieces of information from each key switch. In FIG. 2, this is provided by the shift register 34. It is necessary to know in what octave the key switch is located, and it is also necessary to know which note within the octave corresponds to the key switch. A simple switching circuit to achieve this end is illustrated in FIG. 5. In this instance, a plurality of normally open key switches 102 is connected to a positive voltage supply line 104. The opposite side of each switch is connected to a respective junction point 105. The first twelve of such junction points 105 are connected through respective diodes 106 to an octave collector bus 108. This bus indicates the octave number (i.e. one) of any closed key switch for the octave in question. The next 12 junctions 105 are likewise connected through diodes 106 to an octave collector bus 110, this bus indicating the octave number of the second octave.

In addition, each junction 105 is connected to a second diode 112. There are twelve collector buses 114 corresponding to the various notes, and for example, switches 1, 13, 25, etc. are connected to the C note bus, while switches 2, 14, 26, etc. are connected to the C # note bus, and so forth, switch 12, 25, etc. being connected to the B note bus 114 to complete the octave of notes.

The switching of FIG. 5 is utilized in accordance with the diagram of FIG. 6, wherein the keyboard 116 represents all of the key switches 102. A master clock 118 is provided which has 12 outputs related in accordance with the 12th root of 2. The outputs either are the top twelve of the desired frequencies, or else multiplies thereof. The 12 outputs of the master clock 118 are connected to twelve clock AND gates 120, and the various note buses 114 are respectively connected to those 12 AND gates.

The 12 AND gates are connected by respective wires to twelve divider strings in a divider 122. Each divider string has six dividers to provide a total possible six octaves, thus giving a total of 72 notes, and this is the most generally employed in an electronic organ. The six-octave number buses 108, etc. are connected from the keyboard to the dividers 122 to determine whether each divider will divide by a factor of anywhere from 2 to 64, depending on the octave in which the particular note is played. There are 72 possible frequency outputs, and these are connected to the N-state shift register 54 previously described (including the matrix) and on to the boxcar integrator, etc.

The foregoing circuit or organ generator system is a redundant system, and up to 72 notes (all of the possible notes for the illustration chosen) can be played at the same time. The redundancy can be minimized in accordance with FIG. 7, wherein the master clock 118 is retained as before, having 12 output wires respectively connected to the 12 clock AND gates 120. Similarly, there are 12 note outputs from the keyboard connected to the clock AND gates 120. Rather than having the 12 outputs of the clock AND gates 120 connected direct to divider strings, they are connected to a divider NOR gate with scanner 124. This divider-scanner has five outputs which are connected to a divider 126 having five divider strings of six stages each. The six octave buses 108, etc. are connected to the divider-scanner 124.

If one note is played on the keyboard, the connections simply go through from the clock AND gates and from the six octave buses to the divider strings 126 to produce the necessary output. If a second note is played before the first ends, the scanner (a shift register) simply selects the next divider string. In the present instance, there is a total possible of five different frequency outputs which generally is sufficient for "pop" organ playing. (Note that at least in the case of the pedals, a preference circuit could be used rather than the scanner, since normally only one pedal note is played at a time for "pop" organ playing.) Five has simply been chosen as an illustrative number, and it will be understood that the number of divider strings actually to be employed is equal to the maximum number of notes to be playable at any one time.

The output is in the nature of pulses or square waves, and is connected to the N-state shift register 54 previously mentioned.

The question of playing more than one note at a time arises with the circuit of FIG. 2 the same as it does with the circuit of FIG. 7 and the distributor 48 of FIG. 2 simply passes the second note indication along to the second buffer memory, just as the scanner in FIG. 7 selects the next divider string. In either case, if two notes are played simultaneously, the second will be

passed along and will be delayed perhaps a few microseconds, which is insignificant. As will be appreciated, it is practically a physical impossibility for an organist to play two notes at exactly the same time, and it is reasonable to expect that they will not be closer than microseconds to one another in any event.

It will be apparent from the foregoing that in accordance with the present invention, the information delivered by the keyboard is not that of the frequency of the note selected, but is the position of the note selected. This information is used in accordance with suitable pulse generating devices, and an N-state shift register having a presettable matrix to produce output pulses of varying density on a time base, which when applied to a boxcar integrator, provide the desired audio frequency and wave shape.

The invention is claimed as follows:

1. An electronic keyboard musical instrument comprising a plurality of manually operable keys and a plurality of key switches respectively operated thereby, pulse producing means, means interconnecting said key switches and said pulse producing means to cause said pulse producing means to produce a repeating train of pulses the repetition rate of which is determined by which key switch is operated, integrating means connected to said pulse producing means and receiving and integrating said train of pulses to produce an audio-frequency electric wave corresponding to a musical tone, electro-acoustic translating means, and means connecting said integrating means to said electro-acoustic translating means to produce an audible musical tone.

2. An instrument as set forth in claim 1 wherein said integrating means comprises a boxcar integrator.

3. An instrument as set forth in claim 1 wherein the pulse producing means includes a multi-frequency clock the output of which is controlled by said key switches.

4. A musical instrument as set forth in claim 1 and further including pulse density controlling means connecting said pulse producing means and said integrating means.

5. An instrument as set forth in claim 4 wherein the pulse density determining means includes a shift register.

6. An instrument as set forth in claim 5 and further including manually controllable means for determining the output of said shift register.

7. An instrument as set forth in claim 6 wherein the manually controllable means includes a matrix connected to said shift register.

8. An instrument as set forth in claim 7 wherein the manually controllable means further includes means for adjusting the matrix pattern.

9. An instrument as set forth in claim 8 wherein the means for adjusting the matrix pattern includes a plurality of diode switches.

10. An instrument as set forth in claim 4 wherein the pulse producing means comprises a multi-frequency clock the output of which is determined by said key switches, and the pulse density determining means includes a shift register.

11. An electronic keyboard musical instrument comprising a plurality of manually operable keys and a plurality of key switches respectively operated thereby, a

plurality of like pulse producing and distribution density determining means for producing a repeating train of pulses, distributor means for sequentially connecting said key switches to said plurality of like means, a plurality of integrating means connected to said plurality of like means and receiving and integrating said train of pulses to produce audio-frequency electric waves respectively corresponding to musical tones, means for combining such audio-frequency electric waves, and electro-acoustic translating means connected to said combining means to produce audible musical tones.

12. An instrument as set forth in claim 11 and further including a plurality of buffer memories respectively connecting said distributing means to a plurality of like pulse producing means.

13. An electronic keyboard musical instrument comprising a plurality of manually operable keys and a plurality of key switches respectively operated thereby, pulse producing means, a multi-frequency clock, a plurality of gates connected to the output means of said multi-frequency clock, divider means connected to said gates on the output sides thereof, means interconnecting said key switches with said gates and with said divider means for controlling said gates and said divider means from said key switches to provide a repeating train of pulses from said divider means, the repetition rate of said train of pulses being determined by which key switch is operated, integrating means, means connecting said divider means to said integrated means whereby said integrating means receives and integrates a train of pulses to produce an audio-frequency electric wave corresponding to a musical tone, electro-acoustic translating means, and means connecting said integrating means to said electro-acoustic translating means to produce an audible electrical tone.

14. An instrument as set forth in claim 13 wherein the means connecting the divider means and the integrating means comprises pulse density determining means including a shift register and means providing an adjustable control pattern for said shift register.

15. An instrument as set forth in claim 14 wherein the integrating means comprises a boxcar integrator.

16. An instrument as set forth in claim 13 wherein the means connecting the key switches to the gates and dividing means comprises a shift register controlled by said key switches and a diode tree connected to said shift register on the output side thereof and further connected to said gates and said dividing means.

17. An electronic keyboard musical instrument comprising a plurality of manually operable keys and a plurality of key switches respectively operated thereby, pulse producing means, means interconnecting said key switches and said pulse producing means providing information as to the position of an operated key switch and controlling the operation of said pulse producing means to produce a repeating train of pulses the repetition rate of which is determined thereby, integrating means connected to said pulse producing means and receiving and integrating said train of pulses to produce an audio-frequency electric wave corresponding to a musical tone, electro-acoustic translating means, and means connecting said integrating means to said electro-acoustic translating means to produce an audible electrical tone.

18. An instrument as set forth in claim 17 wherein the information providing means includes means for providing digital information as to the position of an operated key switch.

19. An instrument as set forth in claim 17 wherein the key switch position information providing means includes a shift register, a clock, and a counter, and means interconnecting said key switches respectively with said shift register and said counter, said counter being connected to said pulse producing means and being operative to transfer a count thereto when a respective key switch is operated.

20. An instrument as set forth in claim 19 and further including a plurality of like pulse producing means and a distributor connecting said counter to said like pulse producing means.

21. An instrument as set forth in claim 20 and further including a plurality of like buffer memories respectively connecting said distributor means to said like pulse producing means.

22. An instrument as set forth in claim 17 wherein the information providing means comprises means providing information as to the octave in which a key switch is located and information as to the note position within an octave.

23. An instrument as set forth in claim 22 wherein the information providing means comprises a clock, a plurality of clock gates connected to said clock, a plurality of divider strings connected to said gates on the output side thereof, means connecting the key switches according to note within an octave to said clock gates, and means connecting said key switches to said divider strings and providing information as to the octave within which an operated key switch is located.

24. An instrument as set forth in claim 23 and further including a divider NOR gate with scanner, said clock gate outputs and the key switch octave information bearing means being connected to said divider NOR gate with scanner and the output thereof being connected to said divider strings.

25. In an electronic musical instrument the combination comprising pulse producing means for providing a train of pulses, means for controlling said pulse producing means to determine the repetition rate of said train of pulses, means connected to said pulse producing

means and receiving the output thereof for determining the pulse density pattern of said train of pulses, and pulse receiving means for producing an audio-frequency electric wave having a waveshape determined by said pulse train repetition rate and density, said wave corresponding to a desired musical tone.

26. The combination set forth in claim 25 wherein the pulse receiving means comprises a boxcar integrator.

27. The combination set forth in claim 25 wherein the pulse density determining means comprises a shift register and a variable path therefor.

28. The combination set forth in claim 27 wherein the variable path comprises a matrix and means for adjusting said matrix.

29. The combination set forth in claim 28 wherein the matrix adjusting means comprises a plurality of diode switches.

30. In an electronic musical instrument, the combination comprising a plurality of key switches greater than an octave in number, means providing an electric potential to the inputs of said key switches, a plurality of note output lines respectively corresponding to the notes of an octave, means connecting the key switches of notes of like designation in different octaves to a respective note output line, a plurality of octave output lines, and means connecting key switches of an octave to a respective octave output line.

31. The combination set forth in claim 30 wherein each connecting means comprises a unilaterally conductive isolating means.

32. The combination set forth in claim 30 wherein the pulse producing means has a plurality of output frequencies related to notes in an octave, a plurality of gates, means connecting said note output lines and said pulse producing means to said gates, divider means, and means connecting said gates and said octave output lines to said divider means, activated octave output lines determining the function of division of said divider means.

33. The combination set forth in claim 32 and further including divider NOR gate means, means connecting said previously mentioned gates and said octave output lines to said NOR gate means, and means connecting said NOR gate output to said divider means.

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