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AKIO KAMEOKA ET AL

3,716,647

MUSICAL SOUND GENERATING SYSTEM WITH BURST SIGNALS

Filed Dec. 8, 1971

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FIG. 1

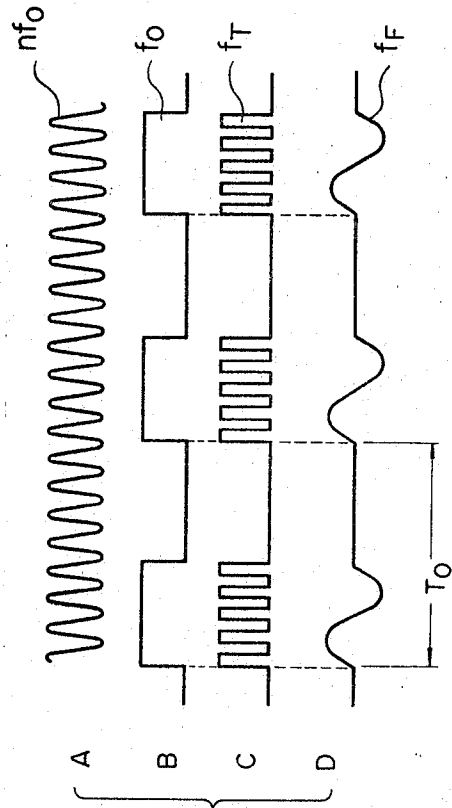
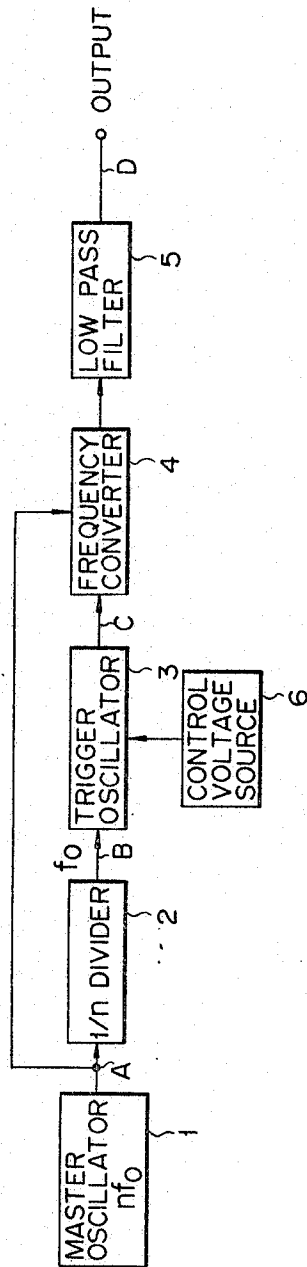


FIG. 2

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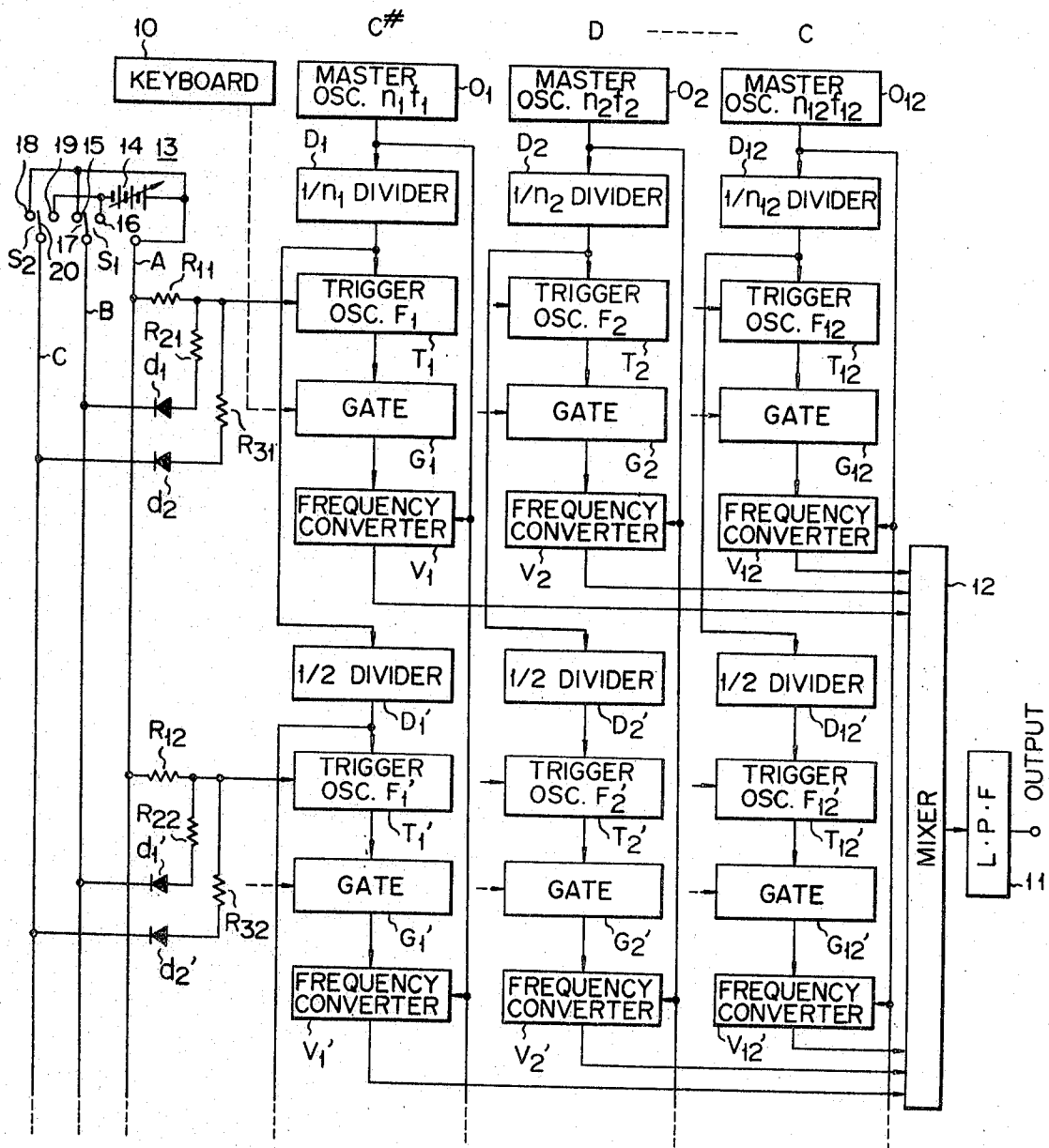
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FIG. 3



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FIG. 4

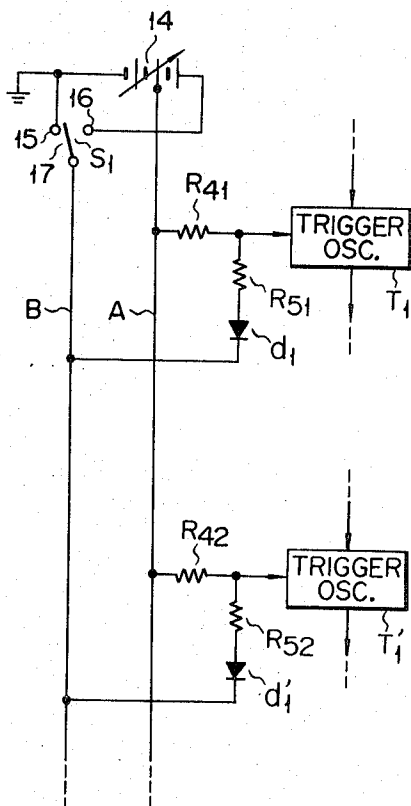


FIG. 5

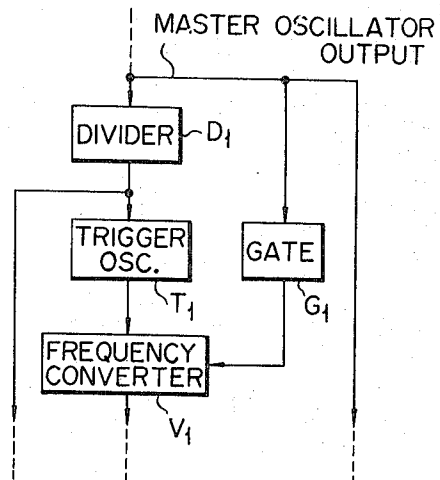
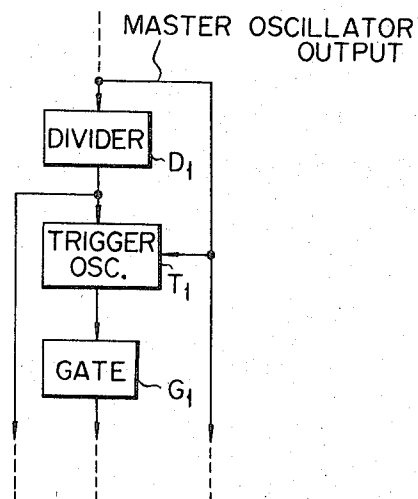


FIG. 6



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MUSICAL SOUND GENERATING SYSTEM WITH BURST SIGNALS

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11 Claims

ABSTRACT OF THE DISCLOSURE

A musical sound generating system for an electronic musical instrument which comprises a master oscillator for producing a signal having a frequency which is integral multiples of a fundamental frequency defining the pitch of a musical sound to be synthesized. The master oscillator output frequency is divided by a frequency divider to obtain a signal of the fundamental frequency. The divider output triggers an oscillator to cause oscillation which is continued during a desired length of time within the period of the fundamental frequency. The trigger oscillator operates at a frequency deviated from the master oscillator frequency by a desired formant frequency associated with the musical sound to be synthesized. The outputs of the master and trigger oscillators are coupled to a frequency converter or amplitude modulator to produce a signal of the formant frequency or difference frequency between master and trigger output frequencies. The output of the frequency converter is then coupled to a low pass filter to produce at the output thereof a burst signal having the instantaneous frequency of the formant frequency. The frequency spectrum envelope of the burst signal has a maximum value at the formant frequency.

BACKGROUND OF THE INVENTION

This invention relates to a musical sound generating system for an electronic musical instrument.

More particularly, the present invention relates to a musical sound generating system comprising a fundamental frequency oscillator for producing a signal of a fundamental frequency defining the pitch of a musical sound to be synthesized; and a formant frequency oscillator for producing a signal of a desired formant frequency associated with the musical sound which is triggered to cause oscillation for a desired length of time during the period of the fundamental frequency by the output of the fundamental frequency oscillator to thereby produce at the output of the formant frequency oscillator a burst signal having a frequency spectrum with the desired formant.

Such a system is disclosed in U.S. Pat. No. 3,668,294, issued on June 6, 1972, and assigned to the same assignee as the present application. With this system, it is desired that the formant frequency oscillator or trigger oscillator be of a type which is controllable in its oscillating frequency to obtain a desired timbre or tone color. Moreover, it is required that the oscillating frequency of the formant frequency oscillator be varied over a relatively broad range. Namely, the necessary highest oscillating frequency must be several times the necessary lowest oscillating frequency. In practice, however, controlling of the oscillating frequency over such a broad range is very difficult.

In synthesizing musical sounds it is sometimes required that the formant envelope in a frequency spectrum have a relatively sharp single-hump characteristic, that is, a large Q. The large Q single-hump formant envelope can be obtained by using a sinusoidal burst signal. The sinusoidal

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burst signal can be produced by using a triangular wave oscillator as a trigger oscillator, and shaping the triangular wave output from the trigger oscillator into sinusoidal wave by means of a non-linear circuit, for example. The reason for the utilization of the triangular wave oscillator as the trigger oscillator resides in that the triangular wave oscillator can be relatively simply controlled in its oscillating frequency as compared with a sinusoidal wave oscillator.

With the construction of an electronic musical instrument or electronic organ utilizing the musical sound generating system mentioned above, there is required a burst signal generating circuit for the respective keys constituting a keyboard of the instrument. As a result, it is necessary to provide for the instrument the same number of triangular wave oscillators (which are complicated in construction) and wave shapers which are each connected to the respective oscillators for shaping the triangular output signal, into sinusoidal signal as the number of keys of the instrument, resulting in a very complicated construction of the instrument.

It is accordingly the object of the present invention to provide a musical sound generating system capable of simply controlling a formant frequency associated with a musical sound to be synthesized.

SUMMARY OF THE INVENTION

According to the present invention there is provided a musical sound generating system comprising master oscillator means for producing a signal of a frequency which is integral multiples of a fundamental frequency defining the pitch of a musical sound to be synthesized; frequency divider means connected to the master oscillator means for producing a signal of the fundamental frequency; trigger oscillator means connected to the frequency divider means which starts oscillation in synchronism with the output from the frequency divider means and continues the oscillation during a desired length of time within the period of the fundamental frequency, the trigger oscillator means having an oscillating frequency which is deviated from the frequency of the master oscillator means by a desired formant frequency associated with the musical sound to be synthesized; means connected to the master and trigger oscillator means for producing a signal of an instantaneous frequency which equals to the difference between the master and trigger oscillator frequencies; and low pass filter means connected to the difference frequency signal producing means for deriving the instantaneous frequency signal out of the output of the difference frequency signal producing means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a basic block diagram of a musical sound generating system in accordance with the present invention;

FIG. 2 shows various waveforms of the outputs of the various stages of FIG. 1;

FIG. 3 is a block diagram of an electronic musical instrument utilizing the musical sound generating system of the present invention;

FIG. 4 is a modification of part of FIG. 3;

FIG. 5 is a modification of part of FIG. 3; and

FIG. 6 is a modification of part of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 reference numeral 1 denotes a master oscillator of an R-C type, for example, for producing sinusoidal signals of frequency nf_0 (n is an integer) as shown in FIG. 2A which are integral multiples of a fundamental frequency f_0 defining the pitch of a musical sound to be synthesized. The frequency nf_0 of master oscillator 1 is

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preferably set above the audible frequency range. Assuming that the fundamental frequency f_0 is 2,093.005 Hz. corresponding to note C_7 , n may be selected to be, for example, 8. In this case, it will be seen that the master oscillator output frequency nf_0 is 16,744.04 Hz.

The output of master oscillator 1 is coupled to a frequency divider 2 which divides an input frequency by n . Thus, the output frequency of the divider 2 equals to the fundamental frequency f_0 . In the case of $n=8$, the divider 2 may be comprised of three stages of flip-flop circuits connected in cascade as is well known.

The divider output as shown in FIG. 2B triggers a trigger oscillator 3 connected thereto to cause oscillation. The trigger oscillator 3 may be an astable multivibrator an example of such a circuit is shown in "Sourcebook of Electronic Circuits," J. Markus, McGraw-Hill, 1968, page 434 which is designed to oscillate during a length of time within the period T_0 of the fundamental frequency f_0 corresponding to positive or negative output portion of the rectangular output (the frequency of which is f_0) from the divider 2. The oscillating frequency f_T of trigger oscillator 3 is set in such a manner that the difference $|nf_0 - f_T|$ between the master oscillator frequency nf_0 and the trigger oscillator frequency f_T equals a formant frequency associated with a musical sound to be synthesized. By way of an example, assuming that a formant frequency f_F of note C_7 is 5 kHz., the trigger oscillator frequency f_T is selected to 21,744.04 Hz., i.e., the sum of the master oscillator frequency nf (in this case, 16,744.04 Hz.) and the trigger oscillator frequency f_T (in this case, 5,000 Hz.). As shown in FIG. 2C, the output of trigger oscillator 3 is a burst signal which has an instantaneous frequency of f_T .

The outputs of master and trigger oscillators are respectively applied to a frequency converter 4 to obtain at the output thereof signals including a signal component having the instantaneous frequency $|nf_0 - f_T|$.

The output of frequency converter 4 is in turn coupled to a low pass filter 5 to eliminate signals of nf_0 and f_T and higher frequency components than nf_0 and f_T including sideband components nearby nf_0 and f_T . Accordingly, the low pass filter output is in the form of a burst signal having the period T_0 of the fundamental frequency f_0 and the instantaneous frequency f_F (formant frequency) during a desired length of time within the period T_0 as shown in FIG. 2D. The burst signal has a frequency spectrum envelope having a maximum value at the formant frequency f_F as disclosed in U.S. Pat. No. 3,668,292, mentioned above. It will be understood that the frequency converter 4 can be replaced by an amplitude modulator.

A control voltage source 6 is connected to the trigger oscillator or astable multivibrator 3 for supplying a control voltage thereto to vary the oscillating frequency f_T of trigger oscillator 3. As is well known, the oscillating frequency can be easily controlled by varying a bias potential associated with one of the transistors constituting the astable multivibrator by means of the control voltage source 6.

In accordance with this invention, as mentioned above, the formant frequency f_F is produced by the difference of the master oscillator frequency nf_0 and the trigger oscillator frequency f_T . Accordingly, the variation of the formant frequency over a relatively broad range can be easily obtained by controlling the relatively high oscillating frequency of trigger oscillator 3 over a relatively narrow range. In addition, when the output waveform of the master oscillator 1 is sinusoidal the burst output signal from the low pass filter 5 is produced in the form of a sinusoidal wave irrespective of the output waveform of trigger oscillator 3. Therefore, a wave shaper is not required to produce a sinusoidal burst signal. The output of trigger oscillator 3 may be of any waveform such as a rectangular, saw-tooth or asymmetrical rectangular waveform if it has the frequency of f_T .

FIG. 3 shows an electronic musical instrument includ-

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ing the musical sound generating system shown in FIG. 1. In the drawing, there are shown twelve master oscillators $O_1, O_2, \dots$ and O_{12} which have oscillating frequencies of $n_1f_1, n_2f_2, \dots$ and $n_{12}f_{12}$ respectively ($n_1, n_2, \dots$ and f_{12} are all integers). The frequencies $f_1, f_2, \dots$ and f_{12} correspond respectively to the fundamental frequencies of twelve notes ($C\sharp, D, \dots, C$) included in the top octave of the musical instrument. The outputs of the master oscillators O_1 to O_{12} are coupled to frequency dividers D_1 to D_{12} respectively which divide input frequencies by $n_1, n_2, \dots$ and n_{12} respectively to obtain at the output sides thereof signals of the fundamental frequencies $f_1, \dots$ and f_{12} .

The respective divider outputs are in turn coupled to trigger oscillators having predetermined oscillating frequencies $F_1, F_2, \dots, F_{12}$ to trigger them and they contain oscillating during desired lengths of time within the periods of the fundamental frequencies. The respective burst output signals from the trigger oscillators T_1 to T_{12} are applied to gate circuits G_1 to G_{12} . As is well known, the gates G_1 to G_{12} are opened to pass signals there-through by key switches when the corresponding top octave keys of a keyboard 10 are depressed and may be designed to provide predetermined rise and decay times to the outputs thereof by utilizing transistors.

The outputs of the gates G_1 to G_{12} and the outputs of the master oscillators O_1 to O_{12} are applied to corresponding frequency converters V_1 to V_{12} concurrently. The respective outputs from the frequency converters V_1 to V_{12} are then coupled to a low pass filter 11 through a mixer 12 to produce the burst signals corresponding to the top octave notes of the instrument.

Moreover, the outputs of the dividers D_1 to D_{12} are coupled to dividers D_1' to D_{12}' respectively which divide input frequencies by two to produce burst signals corresponding to the respective notes included in the octave one octave below the top octave of the instrument. The outputs of the dividers D_1' to D_{12}' are then coupled to second frequency converters V_1' to V_{12}' respectively through second trigger oscillators T_1' to T_{12}' operating at frequencies $F_1', F_2', \dots$ and F_{12}' and second gates G_1' to G_{12}' . To the frequency converters V_1' to V_{12}' there are applied the outputs of master oscillators O_1 to O_{12} in the same manner as the first converters V_1 to V_{12} . It will be noted that the same constructions as mentioned above can be adapted to produce burst signals corresponding to the lower octave notes than the above mentioned two octaves.

To trigger oscillators T_1 to T_{12} and T_1' to T_{12}' is connected frequency controlling means 13. The controlling means includes a variable D.C. voltage source or battery 14, the positive terminal of which is connected to first fixed contacts 15 and 18 of first and second single-pole double-throw switches S_1 and S_2 , for example, respectively while the negative terminal is connected to second fixed contacts 16 and 19 of the switches S_1 and S_2 respectively. Moreover, the positive terminal of the D.C. source 14, and movable contacts 17 and 20 of the switches S_1 and S_2 are connected to first, second and third bus bars A, B and C, respectively. Across the bus bars A and B resistors R_{11} and R_{21} and a diode d_1 with the polarity shown are connected in series. Furthermore, across a juncture between the resistors R_{11} and R_{21} and the bus bar C there are connected in series a resistor R_{31} and a diode d_2 with the polarity shown.

The juncture between the resistors R_{11} and R_{21} is connected to the trigger oscillator T_1 . Across the trigger oscillator T_1' and the bus bars A, B and C there are also connected resistors R_{12} and R_{22} and diodes d_1' and d_2' with the same relationship as that between the trigger oscillator T_1 and bus bars A, B and C. The same connections of resistors and diodes as mentioned above are also provided between other trigger oscillators and bus bars.

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The values of the respective resistors are selected to have such relationships as shown below.

$$R_{11}/R_{21}=R_{12}/R_{22}=\dots$$

$$R_{11}/R_{31}\neq R_{12}/R_{32}\neq\dots$$

With the construction mentioned above, the respective diodes $d_1, d_1', \dots$ are biased in the forward direction when the movable contact 17 if the switch S_1 is connected to the fixed contact 16 connected to the negative terminal of the voltage source 14. Accordingly, to the respective trigger oscillators there are applied a fixed voltage which is determined by the voltage division ratios of $R_{11}/R_{21}, R_{12}/R_{22}, \dots$. If the respective trigger oscillators are adjusted to have oscillating frequencies $F_1, R_2, \dots$ and F_{12} and $F_1', F_2', \dots$ and F_{12}' to satisfy a relationship of

$$F_1 - n_1 f_1 = F_2 - n_2 f_2 = \dots = F_{12} - n_{12} f_{12} = \\ F_1' - n_1' f_1' = F_2' - n_2' f_2' \dots$$

with the applied fixed voltage there may be obtained a so-called "fixed formant" wherein the formant frequencies for the respective notes are identical with each other. The formant frequencies can be varied uniformly with the variation of the voltage value of the source 14.

On the other hand, the respective diodes $d_2, d_2', \dots$ are biased in the forward direction by connecting the movable contact 17 of switch S_1 to the fixed contact 15 thereof and the movable contact 20 of switch S_2 to the fixed contact 19 thereof. As a result, the magnitudes of control voltages which are applied to the respective trigger oscillators are different from each other due to the described relationship $R_{11}/R_{13}\neq R_{12}/R_{32}\neq\dots$. Accordingly, it results in that the formant frequencies are different from each other for the respective notes. With the sequentially increased or decreased division ratios mentioned above in accordance with the pitches or fundamental frequencies there can be produced musical sounds with a so-called "moving formant" wherein the formant frequencies increase or decrease directly in proportion to the pitch frequencies.

As mentioned above, the present invention can provide an electronic musical instrument wherein a player can easily select the fixed formant or moving formant according to the necessity of performance.

FIG. 4 shows a modification of the formant control device of FIG. 3. In this embodiment, the bus bar A is connected to an intermediate potential point of the voltage source 14, and the bus bar B is connected to the movable contact 17 of the switch S_1 , the first fixed contact 16 of which is connected to the positive terminal of the source 14 and the second fixed contact 15 the negative terminal. Across the bus bars A and B there are connected resistors R_{41} and R_{51} and the diode d_1 in series. The junction between the resistors R_{41} and R_{51} is connected to the trigger oscillator T_1 . Also across the bus bars A and B and the trigger oscillators T_1' , resistors R_{42} and R_{52} and the diode d_1' are provided with the same relationship as that of the resistors R_{41} and R_{51} and the diode d_1 . In this case, the magnitudes of the resistors may be selected to have such relationships as $R_{41}=R_{42}=\dots$, and $R_{52}\neq R_{52'}=\dots$.

Upon connecting the movable contact 17 of the switch S_1 to the fixed contact 16 the respective diodes are biased in the backward direction. Accordingly, in this case, a fixed control voltage (a voltage corresponding to the intermediate potential point) is applied to the respective trigger oscillators resulting in the production of fixed formant. Next, by connecting the movable contact 17 of the switch S_1 to the fixed contact 15 the respective diodes are biased in the forward direction. In this case, since the voltage division ratios of $R_{51}/R_{51}, R_{42}/R_{52}, \dots$ are different from each other there is produced a moving formant wherein the formant frequencies for the respective notes differ from each other.

As shown in FIG. 5 the output of the master oscillator

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may be coupled to the frequency converter T_1 through the gate G_1 .

As means for producing the formant frequency based on the difference between the master oscillator and trigger oscillator output frequencies there may be used frequency modulators, pulse width modulators, non-linear circuits such as diode-clippers and the like other than the above-mentioned frequency converters and amplitude modulators.

FIG. 6 shows an embodiment wherein the master oscillator output is coupled to the trigger oscillator to control the oscillating frequency thereof. In this embodiment, the trigger oscillator is designed to have concurrently the same function as that of the frequency converter or amplitude modulator and, for example, the master oscillator output may be superposed on the above-mentioned oscillating frequency control voltage applied to the trigger oscillator T_1 to modulate the oscillating frequency thereof. As another modification, the gate circuit may be designed to have the function of the frequency converter, amplitude modulator and the like.

What is claimed is:

1. A musical sound generating system comprising:

master oscillator means for producing a signal of a frequency which is an integral multiple of a fundamental frequency defining the pitch of a musical sound to be synthesized;

frequency divider means connected to an output of said master oscillator means for producing a signal of the fundamental frequency;

trigger oscillator means connected to an output of said frequency divider means which starts oscillation responsive to, and in synchronism with, the output from said frequency divider means and which continues said oscillation during a predetermined length of time within the period of the fundamental frequency, said trigger oscillator means having an oscillating frequency which is deviated from the output frequency of said master oscillator means by a desired formant frequency associated with the musical sound to be synthesized;

means connected to said master and trigger oscillator means for producing a signal including an instantaneous frequency signal having a frequency which equals the difference between said master and trigger oscillator frequencies, said instantaneous frequency signal including a component corresponding to a formant frequency of the musical sound to be synthesized; and

low pass filter means connected to an output of said difference frequency signal producing means for deriving said instantaneous frequency signal out of the outputs of said difference frequency signal producing means.

2. A musical sound generating system according to claim 1 further comprising frequency control voltage source means connected to said trigger oscillator means for varying the oscillating frequency of said trigger oscillator means.

3. A musical sound generating system according to claim 1 wherein the output frequency of said master oscillator means is above the audible frequency range.

4. A musical sound generating system according to claim 1 wherein the output waveform of said master oscillator means is sinusoidal.

5. An electronic musical instrument comprising:

keyboard means;

master oscillator means for generating a signal of a frequency which is an integral multiple of a fundamental frequency defining the pitch of a musical sound corresponding to one musical note;

first frequency divider means connected to an output of said master oscillator means for producing a signal of said fundamental frequency;

first trigger oscillator means connected to an output of said first frequency divider means which starts oscillation responsive to, and in synchronism with, the output from said first frequency divider means and which continues said oscillation during a predetermined length of time within the period of said fundamental frequency, said first trigger oscillator means having an oscillating frequency which is deviated from the output frequency of said master oscillator means by a desired formant frequency;

first means connected to outputs of said master oscillator and first trigger oscillator means for producing a first signal including an instantaneous frequency signal having a frequency which equals the difference between said master and first trigger oscillator frequencies;

second frequency divider means connected to said first frequency divider means for dividing the output frequency thereof by two;

second trigger oscillator means connected to said second frequency divider means which starts oscillation responsive to, and in synchronism with, the output of said second frequency divider means and which continues said oscillation during a predetermined length of time within the period of the output frequency of said second frequency divider means, said second trigger oscillator means having an oscillating frequency which is deviated from the frequency of said master oscillator means by a desired formant frequency;

second means connected to outputs of said master oscillator and said second trigger oscillator means for producing a second signal including a second instantaneous frequency signal having a frequency which equals the difference between said master and said second trigger oscillator frequencies;

mixer means connected to the outputs of said first and second instantaneous frequency signal producing means;

low pass filter means connected to an output of said mixer means;

first gate means coupled in a first signal path defined by said master oscillator, said first frequency divider means, said first trigger oscillator means, said first instantaneous frequency signal producing means and said mixer means and operatively coupled to a key of said keyboard for selectively enabling said first signal path and producing said first instantaneous frequency signal at the output of said low pass filter means in response to the depression of a first predetermined key of said keyboard corresponding to said musical note; and

second gate means coupled in a second signal path defined by said master oscillator, said second frequency divider means, said second trigger oscillator means, said second instantaneous frequency signal producing means and said mixer means and operatively coupled

to a key of said keyboard for selectively enabling said second signal path and producing said second instantaneous frequency signal at the output of said low pass filter means in response to the depression of a second predetermined key one octave below said first key of said keyboard.

6. An electronic musical instrument according to claim 5 wherein said first and second gate means are connected between said first trigger oscillator means and said first instantaneous frequency signal producing means, and between said second trigger oscillator means and said second instantaneous frequency signal producing means, respectively.

7. An electronic musical instrument according to claim 5 wherein said first and second gate means are connected between said master oscillator means and said first instantaneous frequency signal producing means, and between said master oscillator means and said second instantaneous frequency signal producing means, respectively.

8. An electronic musical instrument according to claim 5 wherein said first and second gate means are connected between said first instantaneous frequency signal producing means and said mixer means, and between said second instantaneous frequency signal producing means and said mixer means, respectively.

9. An electronic musical instrument according to claim 5 further comprising control voltage source means for controlling the oscillating frequencies of said first and second trigger oscillator means.

10. An electronic musical instrument according to claim 9 wherein said control voltage source means includes first supply means to supply identical magnitude control voltages to said first and second trigger oscillator means, and second supply means to supply different magnitude control voltages to said first and second trigger oscillator means.

11. An electronic musical instrument according to claim 10 including switch means selectively connecting said first and second supply means to said first and second trigger oscillator means.

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U. WELDON, Assistant Examiner

U.S. Cl. X.R.

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