United States Patent

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[54] **ELECTRONIC SYNTHESIS OF SOUNDS EMPLOYING FUNDAMENTAL AND FORMANT SIGNAL GENERATING MEANS**

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[21] Appl. No.: **54,889**

[30] **Foreign Application Priority Data**

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Sept. 30, 1969 Japan....................................44/77535

[52] **U.S. Cl.** ....**84/1.01**, 179/1 SA
[51] **Int. Cl.** **G10h 5/06**
[58] **Field of Search** ....84/1.01, 1.11, 1.19, 1.22, 84/1.23; 331/53; 332/22, 23; 179/1 SA

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Primary Examiner—Laramie E. Askin
Assistant Examiner—Stanley J. Witkowski
Attorney—Flynn & Frishauf

[57] **ABSTRACT**

A sound generating system comprising means for producing signals of fundamental frequency, and means for generating formant frequency signals of frequency higher than the fundamental frequency which starts oscillation synchronizingly with said signal of fundamental frequency and continues said oscillation only for a desired length of time during the period of said signals of fundamental frequency, wherein said signals of formant frequency are generated at the same starting point for each frequency interval as said signals of fundamental frequency. Sounds thus produced consist of a fundamental frequency component and harmonic components, and the frequency spectrum of said sounds presents a peak in a formant frequency, so that the system eliminates the necessity of using an electrical filter having complicated frequency characteristics in electrically producing sounds having a complicated frequency spectrum.

13 Claims, 27 Drawing Figures

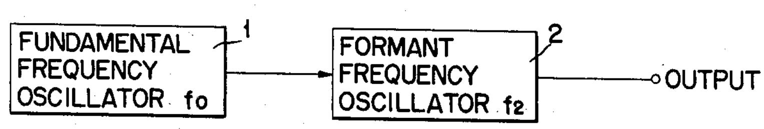


FIG. 1

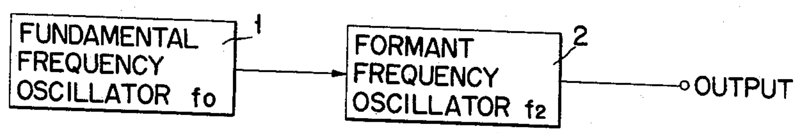
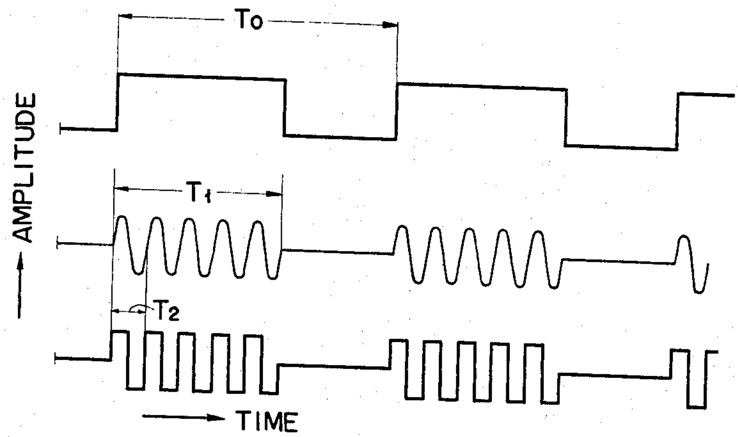


FIG. 2A

FIG. 2B

FIG. 2C



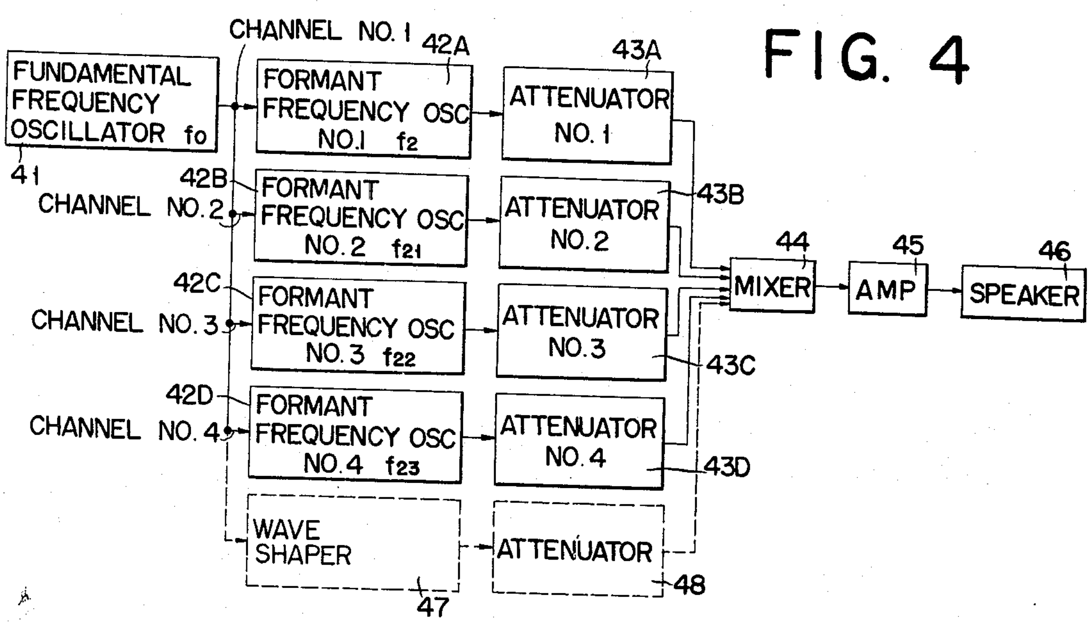


FIG. 4

FIG. 3A

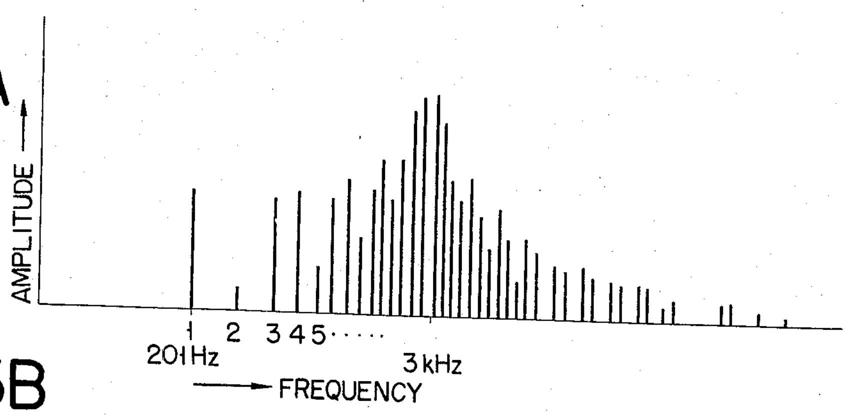


FIG. 3B

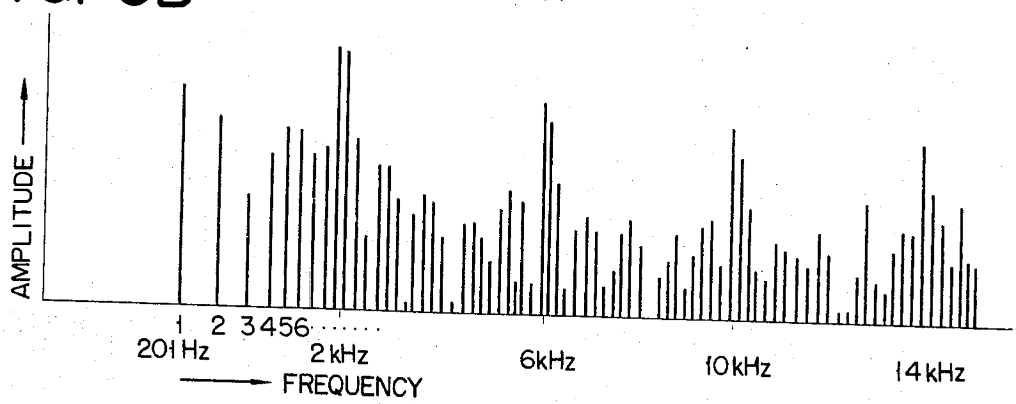


FIG. 6A

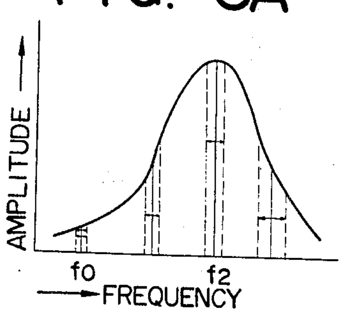


FIG. 6B

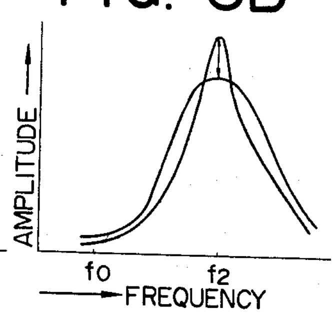


FIG. 6C

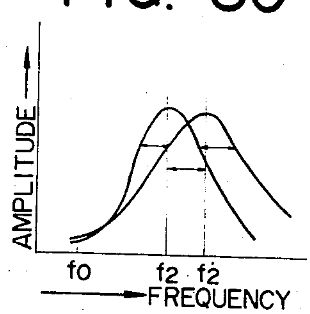
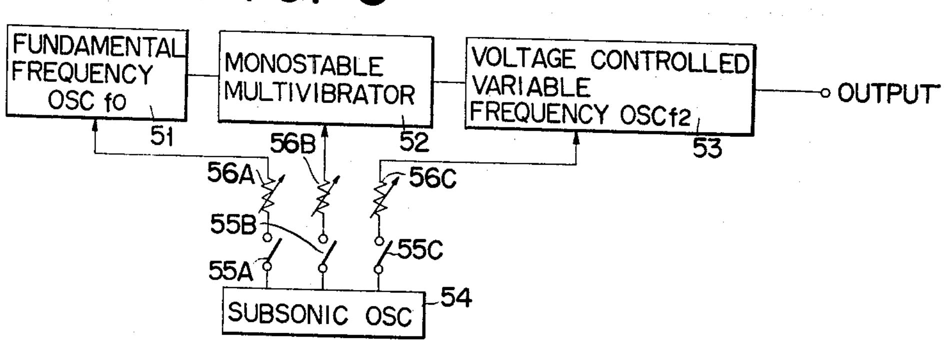


FIG. 5



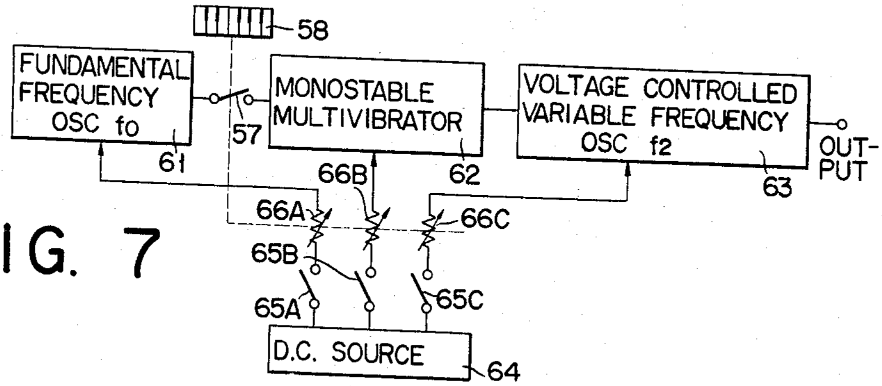
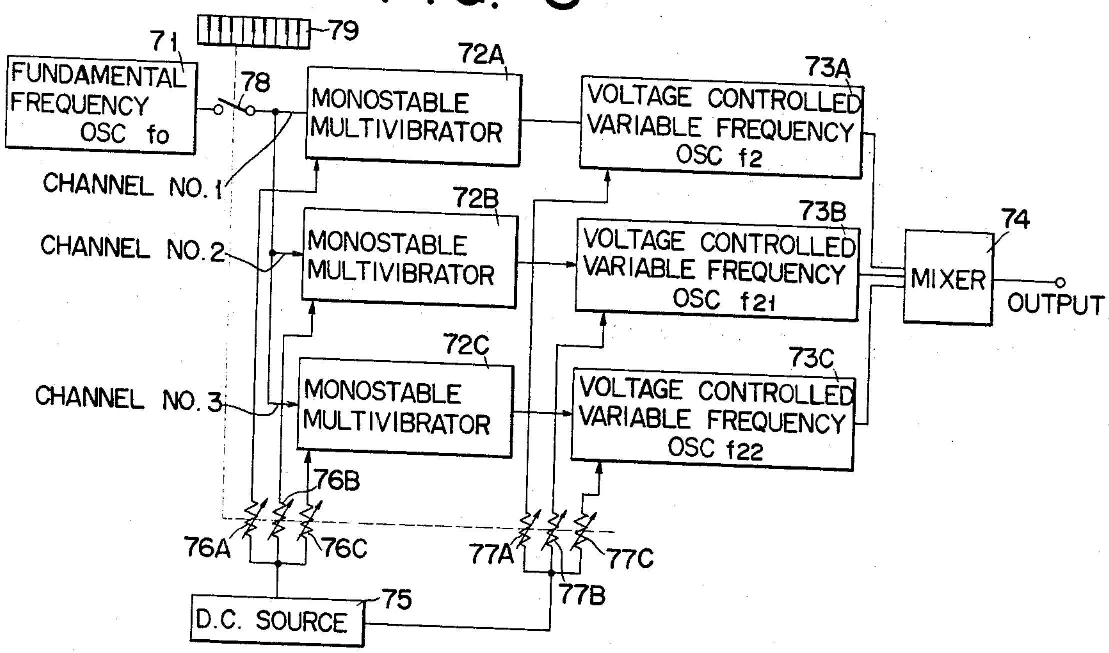


FIG. 7

FIG. 8



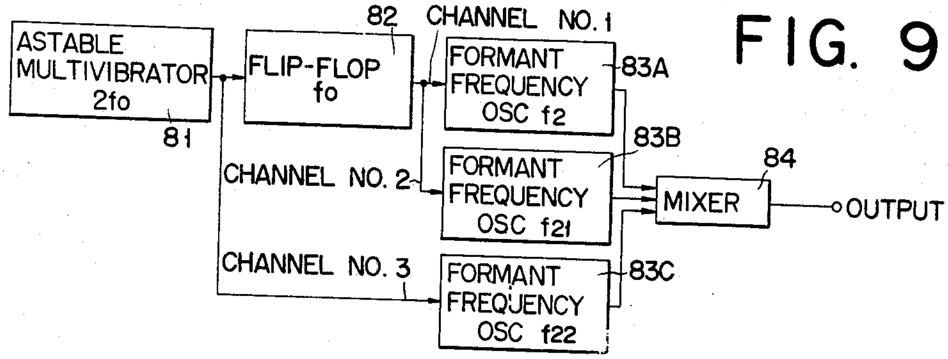


FIG. 9

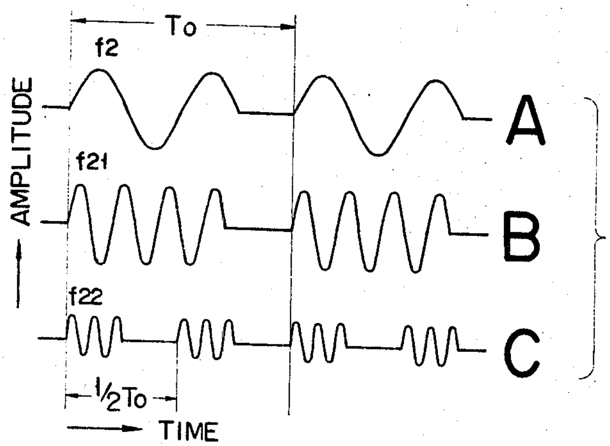


FIG. 10

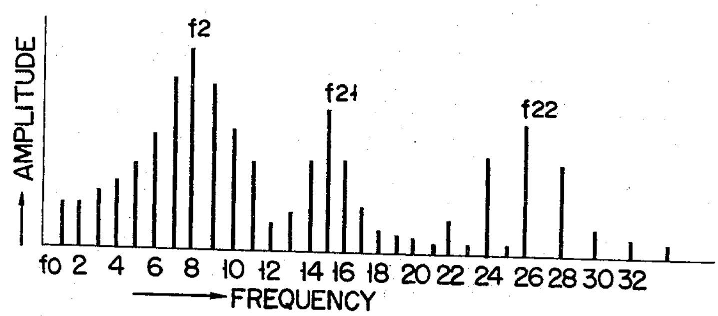


FIG. 11

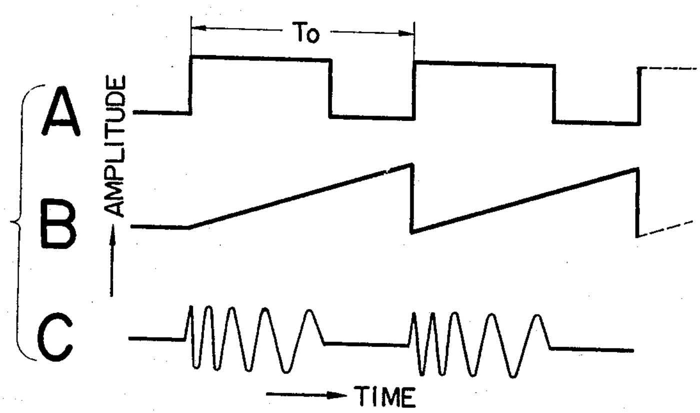


FIG. 13

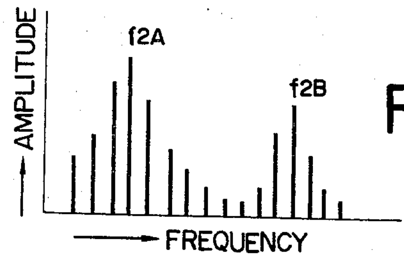


FIG. 16

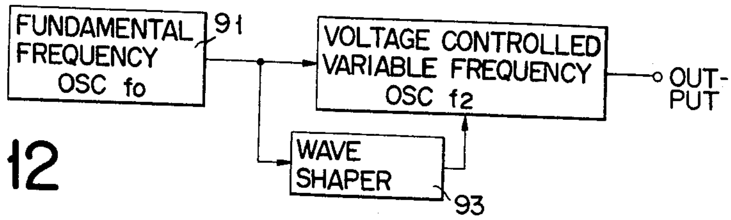


FIG. 12

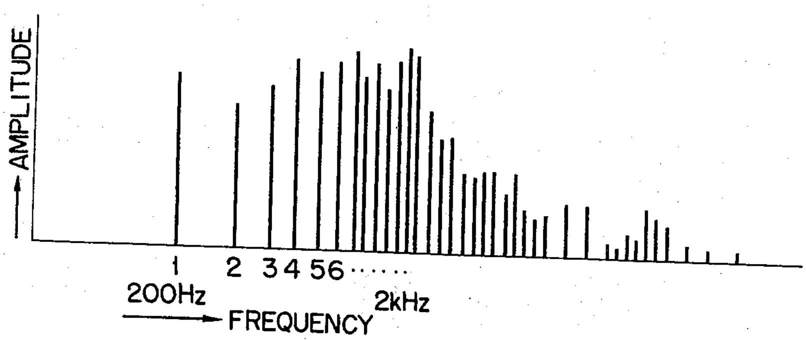


FIG. 14

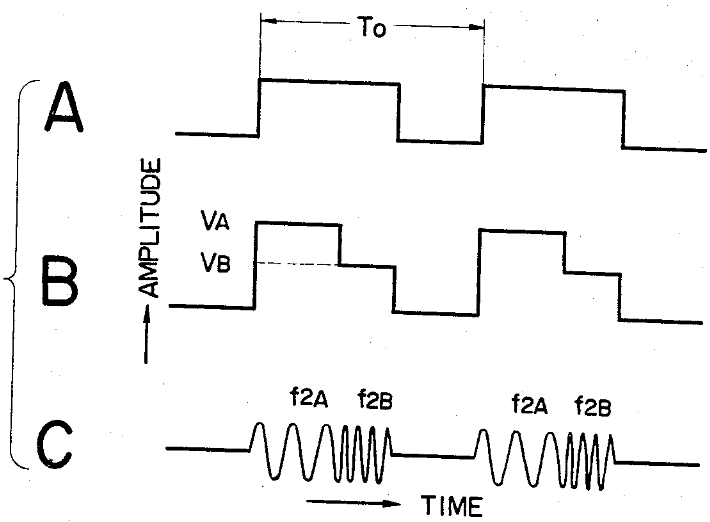


FIG. 15

ELECTRONIC SYNTHESIS OF SOUNDS EMPLOYING FUNDAMENTAL AND FORMANT SIGNAL GENERATING MEANS

BACKGROUND OF THE INVENTION

The present invention relates to a system for generating sounds and more particularly to a system for producing, for example, musical tones or human speech sounds which include a fundamental frequency component and harmonic components.

Human speech sounds and tones of musical instruments include a fundamental frequency component defining the basic pitch and harmonic components associated with the fundamental frequency. The frequency spectrum of the speech sounds and musical tones are extremely complicated, the harmonic components comprising a number of local crests and valleys. Frequencies corresponding to the peak values of these local crests represent formant frequencies.

The musical tone synthesizer of an electronic musical instrument capable of electrically composing the tone colors of various musical instruments has heretofore consisted of a tone generator for giving forth signals having such wave forms as include predetermined fundamental frequency components and numerous harmonic components associated therewith and a tone color filter for modifying outputs from said tone generator to a frequency spectrum having a predetermined envelope.

The above-mentioned tone color filter comprises a plurality of unit filters having different frequency characteristics so as to match the complicated frequency spectra possessed by the tone colors of various musical instruments. Such a tone color filter member comprising several filters has fixed frequency characteristics. Accordingly, use of a single tone color filter member will present difficulties in fully covering a broad frequency range possessed by musical and/or speech tones, failing to produce them in the desired form. Accordingly, it has generally been the practice to divide the frequency range of tones of a particular musical instrument into several parts and use a number of tone color filters to match said divisions of the frequency range. Thus the conventional electronic musical instrument involves a large number of complicated tone color filters and in consequence a great many inductors and capacitors constituting the filters.

In recent years, there has been increasingly applied the integration of electrical circuits in various fields. Where, however, there are required a large variety of inductors and capacitors for the tone color filters as in an electronic musical instrument, it is difficult for the present day technique to integrate the filter circuits. Such integration would unavoidably result in extremely high production cost. If an electronic musical instrument did not require numerous complicated tone color filters in synthesizing musical tones, then its cost would be prominently reduced due to the integration of other electrical circuits than the filters as well as due to elimination of the filters.

Further, the aforesaid tone color filter is used per se common to musical tones having several pitches, so that variation of the pitch of musical tones supplied to said filter will most likely change the formant frequency associated therewith. As previously mentioned, the tone color filter element used in the prior art electronic musical instrument has fixed frequency characteristics, so that output levels of the fundamental and harmonic components derived from said tone color filter element will vary from pitch to pitch. Accordingly, there sometimes occur the cases where there are not presented formants or crests in the predetermined formant frequency region.

Further, such a tone color filter which is intended to cover a relatively broad frequency range presents difficulties in producing outputs having the formant frequency involved in the frequency spectrum at such a level as is sufficient to display sharp frequency characteristics, namely, to have a large quality factor Q. Consequently, the filter element generates outputs having relatively plain frequency characteristics. This

means that the formant frequency region has a fixed envelope shape which can not be varied at will.

It is accordingly an object of the present invention to provide a system for generating sounds such as musical tones and speech sounds adapted for use in an electronic musical tone generator, electronic musical instrument, speech synthesizer and computer musical tone generator, etc. which eliminates the necessity of using an electrical filter having characteristics conforming with the envelope of the frequency spectrum of musical tones and speech sounds when they are to be electrically generated.

Another object of the invention is to provide a sound generating system capable of freely controlling the formant frequencies.

Still another object of the invention is to provide a system for generating sounds of relatively high harmonic frequency having good consonance, that is, little contaminated with turbidity.

A further object of the invention is to provide a sound generating system capable of adjusting the shape of the envelope of the formant frequency region freely, namely, in some cases controlling the envelope so as to present sharp frequency characteristics and in others to display relatively plain frequency characteristics.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a sound generating system comprising means for producing signals of fundamental frequency, and means for generating signals having a prescribed formant frequency higher than the fundamental frequency which starts oscillation synchronously with the signals of fundamental frequency and continues said oscillation only for a desired length of time during the period of said signals of fundamental frequency.

Another feature of the invention resides in means for adjusting the fundamental frequency, formant frequency and the duration of signals having said frequencies at once, separately or in combination.

Still another feature of the invention resides in controlling by fundamental frequency signals that of a plurality of formant frequency oscillators having different frequencies which generates signals of a relatively low frequency and controlling that oscillator which produces signals of a relatively high frequency by signals having frequency equal to integral multiples of the fundamental frequency.

A further feature of the invention resides in controlling formant frequency oscillators by signals having a wave form obtained in synchronism with fundamental frequency signals to modulate said formant frequency in frequency.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 represents a basic block diagram of a sound generating system according to the present invention;

FIG. 2A shows the wave form of outputs from the fundamental frequency oscillator of FIG. 1; FIGS. 2B and 2C indicate two wave forms of outputs from the formant frequency oscillator of FIG. 1;

FIG. 3A illustrates a frequency spectrum of the signals of FIG. 2B; FIG. 3B indicates a frequency spectrum of the signals of FIG. 2C;

FIG. 4 is a block diagram of a sound generating system according to an embodiment of the invention;

FIG. 5 is a block diagram of another embodiment of the invention;

FIGS. 6A, 6B and 6C show schematic envelopes of frequency spectra illustrative of the embodiment of FIG. 5;

FIG. 7 is a block diagram of another embodiment of the invention;

FIG. 8 is a block diagram of still another embodiment of the invention;

FIG. 9 is a block diagram of a further embodiment of the invention;

FIGS. **10A**, **10B** and **10C** represent the wave forms of outputs from the formant frequency oscillators shown in FIG. **9**;

FIG. **11** is a frequency spectrum of outputs from the system of FIG. **9**;

FIG. **12** is a block diagram of a still further embodiment of the invention;

FIGS. **13A**, **13B** and **13C** are the wave forms of outputs from the respective elements of FIG. **12**;

FIG. **14** shows a frequency spectrum of outputs from the system of FIG. **12**;

FIGS. **15A**, **15B** and **15C** illustrate other wave forms of outputs from the respective elements of FIG. **12**; and

FIG. **16** is a frequency spectrum of outputs from the system of FIG. **12** when they have the wave forms illustrated in FIGS. **15A**, **15B** and **15C**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

There will now be described the principle of the present invention by reference to FIG. **1**. Outputs from a fundamental frequency oscillator **1** which is operated with a period T_0, that is, with the fundamental frequency f_0 of musical tones or speech sounds to be synthesized are supplied to control the oscillation of a formant frequency oscillator **2** which is operated with a frequency higher than the fundamental frequency f_0, namely, with a frequency f_2 (period T_2) equal to the formant frequency of musical tones or speech sounds to be synthesized. The formant frequency oscillator **2** is so designed as to start oscillation for each period T_0 of the fundamental frequency f_0 and continue said oscillation only for a desired length of time T_1 during the period T_0. Accordingly, outputs from the formant oscillator **2** may be deemed as an intermittent series of instantaneous frequency signals equal to the formant frequency appearing during each period of the fundamental frequency.

The aforesaid frequencies and their periods have the following relationships:

$T_0 = 1/f_0$

$T_2 = 1/f_2$

The above-mentioned fundamental frequency oscillator **1** may comprise, for example, an astable multivibrator. Outputs therefrom assume, as shown in FIG. **2A**, a rectangular wave whose period T_0 corresponds to the fundamental frequency.

The aforementioned formant oscillator **2** may comprise for example, a ringing or pulsed oscillator. Upon receipt of a positive output component of a rectangular wave illustrated in FIG. **2A**, said oscillator starts operation, and continues oscillation with sine wave outputs only during the period T_1 corresponding to that of the positive outputs from the fundamental frequency oscillator **1** as; shown in FIG. **2B**. Such intermittent oscillation outputs are hereinafter referred to as burst output signals. Since the instantaneous or formant frequency is chosen to be higher than the fundamental frequency, the period T_2 of the oscillation outputs having an instantaneous frequency is smaller than the period T_0 of the fundamental frequency.

The aforesaid formant frequency oscillator **2** may also comprise an astable multivibrator. In this case, it is only required to activate the multivibrator with positive outputs from the fundamental frequency oscillator **1**. At this time there are obtained burst output signals having a triangular wave or a rectangular wave shown in FIG. **2C**. Such triangular wave or rectangular wave outputs may be shaped into sine waves through a non-linear circuitry.

Further, the aforementioned fundamental frequency oscillator **1** may comprise a monostable or bistable multivibrator or sine wave oscillator. After all, according to the invention, it is only required that the formant frequency oscillator be so designed as to start operation in synchronism with outputs from the fundamental frequency oscillator and stop oscillation within a prescribed length of time during the period of the fundamental frequency.

There will now be further theoretically described the fact that sine wave burst output signals from the formant frequency oscillator **2** which have a repetitive period equal to the fundamental frequency period T_0 and continue to be oscillated only for a smaller length of time T_1 than T_0, have a musical sound frequency spectrum consisting of a fundamental frequency component and harmonic components associated therewith.

It is well known that a periodic function $F_0(t)$ derived from repetition of the same wave every T_0 second may generally be divided into higher order harmonics having frequencies equal to integral multiples of the fundamental frequency f_0. Here is applicable the aforesaid relationship $T_0 = 1/f_0$.

The aforesaid periodic function $F_0(t)$ may be resolved as follows:

$$F_0(t) = 1/2a_0 + \sum_{n=1}^{\infty} (a_n \cos nW_0t + b_n \sin nW_0t) \ldots \quad (1)$$

where:

$$a_n = 2/T_0 \int_0^{T_0} F_0(t) \cos nW_0t \, dt (n = 1, 2, 3 \ldots)$$

$$b_n = 2/T_0 \int_0^{T_0} F_0(t) \sin nW_0t \, dt (n = 1, 2, 3 \ldots)$$

$$W_0 = 2\pi f_0 = 2\pi/T_0$$

The amplitude A_n of harmonic frequency component of the nth order may be expressed as follows:

$$A_n = \sqrt{a_n^2 + b_n^2} \quad (2)$$

Analysis of the equations (1) and (2) shows tat the envelope of the frequency spectrum associated with the periodic function $F_0(t)$ shown in FIG. **2B** includes a formant component possessing a maximum value at an instantaneous frequency f_2 appearing during oscillation. The shape of this formant varies in complicated form with the values of T_0, T_1 and T_2. Accordingly, change of these parameters enables formant to be composed in various forms.

Actual analysis of frequency shows that where a burst output signal had a sine wave illustrated in FIG. **2B** and the fundamental period T_0 stood at **1/201** second, one period T_2 of a sine wave at **1/3000** second, and the duration T_1 of a burst output signal at **5/3000** second, then there was obtained a frequency spectrum shown in FIG. **3A**. In this case, the frequency interval between harmonic waves and adjacent ones is equal to the fundamental frequency f_0 = 201 Hz. Namely, there is formed near the 3 kHz region of the frequency spectrum a formant whose formant frequency f_2 stands at the instantaneous frequency of 3 kHz. It should be noted at this point that since the fundamental frequency f_0 is 201 Hz, harmonic components associated therewith do not include a 3 kHz frequency component and however the envelope of the frequency spectrum has a maximum value at 3 kHz.

Musical tones and speech sounds, particularly vowels, often contain more than two formants, necessitating formation of a plurality of formants in order to simulate such tones and sounds. In such case, it is advisable to generate in parallel a plurality of signals shown in FIG. **2B** and then mix them. This embodiment is presented in FIG. **4**.

Referring to FIG. **4**, outputs from a fundamental frequency oscillator **41** which is operated with a period of T_0 is branched off into, for example, four channels. The channels comprise formant frequency oscillators **42A**, **42B**, **42C** and **42D** connected to attenuators **43A**, **43B**, **43C** and **43D** in cascade, respectively. These formant frequency oscillators **42A**, **42B**, **42C** and **42D** are so designed as to be oscillated with such formant frequencies f_2, f_{21}, f_{22} and f_{23} as are contained in the musical tones or speech sounds to be synthesized. Where an output from the formant frequency oscillator consists of a sine wave, said output is supplied to the attenuator and an output from the attenuator is conducted to a mixer **44**. If an output from the formant frequency oscillator does not consist of a sine wave, but a triangular or rectangular wave, for example, then said output is shaped into a sine wave by a suitable wave shaper (not shown) consisting of, for example, a non-linear circuit, and thereafter supplied to the attenuator. Mixed outputs from the mixer **44** is conducted to an amplifier **45** so as to have a sufficient magnitude to actuate a loud-speaker **46**. Thus are composed musical tones or speech sounds having four formant frequencies. The number of the aforesaid channels may be increased or decreased as required.

Further as shown by the dotted lines of FIG. **4**, a rectangular wave output from the fundamental frequency oscillator **41** may be supplied to the mixer **44** through a separate attenuator **48** after being shaped into a sine wave by a wave shaping circuit **47**, or directly without such shaping, thereby to elevate the level of the fundamental frequency component or lower harmonic component.

In the aforesaid embodiment, output burst signals from the formant frequency oscillator were assumed to consist of a sine wave. However, where the burst signal consists of a rectangular wave illustrated in FIG. **2C**, then it is possible, as shown in FIG. **3B**, to generate by a single channel circuit of FIG. **1** a plurality of formants each having a formant frequency equal to an odd multiple of that which is produced in case of a sine wave. The frequency spectrum of FIG. **3B** was obtained by analysis in case the parameters had the following values:

$T_0 = 1/201$ second

$T_1 = 8/2000$ second

$T_2 = 1/2000$ second.

Where the burst signal is formed of a saw-tooth wave, it is possible to generate a plurality of formants each having a formant frequency equal to an integral multiple of that which is produced in case of a sine wave. Thus there can be synthesized a large variety of formants according to the wave forms to be employed. Further, if required, it is possible to use a combination of burst signals having a sine wave, rectangular wave and saw-tooth wave.

The aforesaid analysis is associated with the case where the parameter T_1 was an integral multiple of T_2. However, such integral multiple is not always required. In the frequency spectrum where T_1 does not represent an integral multiple of T_2, harmonics of higher frequencies than a formant frequency have a slightly increased level, but the levels at the formant frequency region and the lower frequency region do not present any appreciable differences.

As described above, variation of the parameters of T_0, T_1 and T_2 associated with intermittent oscillation output signals or output burst signals can modify the frequency spectrum. Accordingly, provision of means for changing the parameters T_0, T_1 and T_2 is expected to display various tonal effects. An embodiment involving such means is presented in FIG. **5**.

Referring to FIG. **5**, there are cascade connected a fundamental frequency oscillator **51**, monostable multivibrator **52** and a voltage controlled variable frequency oscillator **53** corresponding to the aforementioned formant frequency oscillator. In this case, the fundamental frequency oscillator **51** may consist of an astable multivibrator and the voltage controlled variable frequency oscillator may be formed of, for example, a triangular wave oscillator including a Miller integrator. Referring again to FIG. **5**, there is provided a subsonic oscillator **54** as a source of modulating signals. Output signals from said oscillator **54** are supplied to the controlled circuits of the fundamental frequency oscillator **51**, monostable multivibrator **52** and voltage controlled variable frequency oscillator **53** through control switches **55A**, **55B** and **55C** and variable impedance elements **56A**, **56B** and **56C**.

Output signals from the subsonic oscillator **54** may consist of a sine wave or triangular wave having a frequency of, for example, 6Hz. In this case, the level of said output signals is controlled by the variable impedance elements **56A**, **56B** and **56C** separately. Outputs from the subsonic oscillator **54** are separately supplied to the aforesaid controlled circuits through selective operation of the control switches **55A**, **55B** and **55C**.

When the base electrode of two transistors constituting an astable multivibrator used as a fundamental frequency oscillator is supplied with repetitive modulating signals from the subsonic oscillator **54**, then the period T_0 of the fundamental frequency varies with the same repetitive period as that of the modulating signals. Where, therefore, the following monostable multivibrator **52** and formant frequency oscillator **53** are not supplied with modulating signals, then the frequency spectrum envelope of burst signals from the formant frequency oscillator **53** whose triangular wave has been shaped into a sine wave varies as illustrated in FIG. **6A**, in such a manner as to allow the fundamental frequency component to vary with the same repetitive period as that of modulating signals. It will be apparent that in this case, the frequency of a harmonic component is deviated to an extent equal to the deviation of the fundamental frequency multiplied by the number of the order assumed by the harmonic component. Variation of the fundamental frequency represents per se a vibrato effect.

When the base electrode of one of the two transistors constituting the monostable multivibrator **52** is supplied with modulating signals by conduction of the control switch **55B** alone, it is possible to vary only T_1 with the frequency period T_0 kept intact. In this case, there occurs change only in the duration of burst output signals from the formant frequency oscillator **53**. Variation of a frequency spectrum envelope resulting from change of an oscillation duration T_1 alone is indicated by modulation of the formant frequency region as shown in FIG. **6B**. Namely, the envelope of the formant frequency region repeatedly changes from a plain to a sharp pattern. In other words, the quality factor Q, or degrees of sharpness repeatedly changes.

There will now be described the case where the voltage controlled variable frequency oscillator **53** alone is supplied with modulating signals by conduction of only the control switch **55C**. This oscillator uses a Miller integrator. In this case, output signals having a triangular wave are shaped into a rectangular wave, the rectangular wave output signals being fed back to the input side. The oscillating frequency is varied by changing the voltage level of the rectangular wave by modulating signals. Accordingly, the instantaneous frequency of burst signals, that is, the formant frequency f_2 is repeatedly varied. In this case, the frequency spectrum varies as shown in FIG. **6C**, namely, in such a manner that while the fundamental frequency remains unchanged, the formant frequency is deviated across f_2 and f_2' causing the formant to be varied with the same repetitive period as that of the modulating signals.

As mentioned above, modulation by low frequency signals of the parameters T_0, T_1 and T_2 separately or in combination permits synthesis of a large variety of AM or FM patterns and complicated modulated patterns involving a mixture thereof, namely synthesis of dynamic timbres.

The embodiment of FIG. **5** relates to the case where the parameters T_0, T_1 and T_2 were modulated by low frequency signals. However, transient change may be effected by DC voltage. This embodiment is presented in FIG. **7**.

The basic construction of FIG. **7** is the same as that of FIG. **6**. In this case, a source of modulating signals may consist of a DC source **64** whose voltage is made to change transiently with a suitable time constant. Between a fundamental frequency oscillator **61** and monostable multivibrator **62** is positioned a switch **57** actuated by operation of the key of the keyboard **58** of an electronic musical instrument. Further, there are provided variable impedance elements **66A**, **66B** and **66C** which are so designed as to have their values varied with key operation. When, with such arrangement, the variable impedance elements are transiently varied in magnitude within a certain length of time after key depression, the fundamental frequency oscillator **61**, monostable multivibrator **62** and voltage controlled variable frequency oscillator **63** are supplied with modulating signals whose voltage changes transiently.

Where the base electrode of one of two transistors involved in the fundamental frequency oscillator **61** consisting of an astable multivibrator is supplied with modulating signals whose voltage transiently changes by conduction of the switch **65A** alone, then there occur transient changes in the fundamental frequency or period T_0. There is realized the so-called portamento effect in which the pitch transiently changes.

Where the base electrode of one of the transistors involved in the monostable multivibrator 62 is supplied with the same modulating signals as in the preceding case by conduction of the switch 65B alone, then the parameter T_1 is transiently varied with the resultant transient change of the Q of formant from a small to a large value or vice versa. The larger the Q value of the formant, the more prominent the distinction between the fundamental frequency component and formant frequency component.

Where the voltage controlled variable frequency oscillator 63 is supplied with the same modulating signals as before by conduction of only the switch 65C, then the parameter T_2, namely, the formant frequency transiently changes. Such transient increase or decrease of the formant frequency impresses the hearer with unique sounds and also realizes a formant glide effect. As mentioned above, the transient variation of the parameters T_0, T_1 and T_2 permits tone colors to be expressed over a much broader range than has heretofore been possible. It will be apparent that the embodiments of FIGS. 5 and 7 may be used in combination.

Further development of the preceding embodiments permits a scat to be played by an electronic musical instrument. This embodiment is presented in FIG. 8.

According to FIG. 8, output signals from the fundamental frequency oscillator 71 are branched off into three channels. The channels comprise, as in the embodiments of FIGS. 5 and 7, monostable multivibrators 72A, 72B and 72C and voltage controlled variable frequency oscillators 73A, 73B and 73C respectively connected in cascade relationship. Output signals from the voltage controlled variable frequency oscillators are supplied to a mixer 74. Voltage from a DC source 75 used as a source of modulating signals is supplied through two groups of variable impedance elements 76A — 76B — 76C and 77A - 77B - 77C to monostable multivibrators 72A, 72B and 72C and voltage controlled variable frequency oscillators 73A, 73B and 73C, thereby changing the duration and frequencies f_2, f_{21} and f_{22} of burst signals occurring in the channels. Between the fundamental frequency oscillator 71 and monostable multivibrators 72A, 72B and 72C is disposed a switch 78 operated upon depression of the keys of keyboard 79 of an electronic musical instrument. The variable impedance elements are so designed as to interlock with the keys and be continuously varied in value for a certain length of time after their depression.

The reason why there are provided three channels as described above is that three formants are considered fully sufficient to simulate human speech sounds. Where there is played, for example, a tone /ṙa/ by the embodiment of FIG. 8, it is only required to generate a formant corresponding to a semivowel r at the instant of key depression and, within a certain length of time after key depression, dynamically to convert said formant to another formant corresponding to a vowel a . Thus is synthesized a speech sound ra of a predetermined pitch, permitting the playing of a desired scat by combination of sounds /ṙa/ of other pitches.

Where, however, outputs from a single fundamental frequency oscillator are branched off into a plurality of channels to generate a plurality of formants, as in the embodiment of FIG. 8, there occur the undermentioned difficulties. Namely, the frequency spectrum in this case comprises a fundamental frequency component and a plurality of harmonics arranged in successively higher orders at frequency intervals equal to the fundamental frequency. Therefore, in the formant frequency region involved in the high frequency range adjacent harmonics bear a frequency ratio approximating 1, leading to lack of consonance or turbidity. Although it may be contemplated, therefore, to prevent formants from being generated in the high frequency range or remove them therefrom so as to obtain an improved consonance, such procedure will cause the formant frequency region to lose its vowel characteristics.

FIG. 9 represents an embodiment devised to eliminate such drawbacks. Referring to this figure, outputs from an astable multivibrator 81, for example, whose oscillating frequency is twice the fundamental frequency f_0 are supplied to a flip-flop circuit 82 used as a ½ frequency divider, obtaining outputs of fundamental frequency. Said fundamental frequency outputs are branched off, as in the preceding embodiments, into a plurality of (for example, two) channels, outputs from said channels being conducted to formant frequency oscillators 83A and 83B. Burst output signals from the formant frequency oscillator 83A associated with the channel 1 which is operated with a relatively low frequency f_2 assume a wave form illustrated in FIG. 10A and those from the formant frequency oscillator 83B associated with the channel 2 which is operated with a frequency f_{21} slightly higher than the aforesaid frequency f_2 assume a wave form shown in FIG. 10B, said burst output signals from both oscillators 83A and 83B being supplied to a mixer 84.

Further, burst output signals from the astable, multivibrator 81 are supplied to another format frequency oscillator 83C associated with the channel 3 which is operated with a frequency f_{22} relatively higher than the aforementioned two frequencies f_2 and f_{21}, said burst output signals from the oscillator 83C being also conducted to the mixer 84.

Output signals from the mixer 84 display a frequency spectrum shown in FIG. 11. The two formants formed of the burst output signals from the formant frequency oscillators 83A and 83B are arranged at the same frequency interval as in the foregoing embodiments. However, the formant frequency oscillator 83C is supplied with input signals which have a frequency twice the fundamental frequency, that is, a frequency period equal to half the fundamental frequency period T_0, so that adjacent harmonic waves included in a formant frequency region which are formed of burst output signals from said oscillator 83C have a frequency interval twice the fundamental frequency. Accordingly, in the formant region involved in the high frequency range, adjacent harmonics are prevented from assuming a frequency ratio approximating 1, obtaining clear tones free from turbidity.

In the embodiment of FIG. 9, the formant frequency oscillator 83C was supplied with input signals whose frequency was twice the fundamental frequency. However, there may be supplied other input signals having a higher frequency equal to an integral multiple (for example, 3 or 4 fold) of the fundamental frequency. Further, the second formant frequency oscillator 83B may be supplied with input signals having a frequency twice the fundamental frequency. The astable multivibrator may comprise a sine wave oscillator, in which case the frequency divider used may be of an ordinary type.

FIG. 12 illustrates an embodiment for modifying the envelope of formants. According to this embodiment, output signals from a fundamental frequency oscillator 91 are supplied to a voltage controlled variable frequency oscillator 92, and to a wave shaper 93 to have their wave forms properly shaped. Output signals from the wave shaper 93 are supplied to the voltage controlled variable frequency oscillator 92 to change its oscillation frequency f_2.

Output signals from the fundamental frequency oscillator 91 having a wave form illustrated in FIG. 13A may be so shaped by the wave shaper 93 as to assume, for example, a saw-tooth wave shown in FIG. 13B whose voltage linearly changes. Said saw-tooth wave output signals are supplied to the voltage controlled variable frequency oscillator 92 to modulate its frequency as shown in FIG. 13C.

Where the output frequency is allowed to be deviated to an extent of from 1 to 2 kHz, then burst output signals from the voltage controlled variable frequency oscillator 92 will present a frequency spectrum shown in FIG. 14, where there predominates the level of harmonic waves having a relatively low frequency of less than 2 kHz, presenting as a whole a plain formant pattern. Further, control of the level of output signals from the wave shaper 93 enables the frequency of the voltage controlled variable frequency oscillator 92 to be freely controlled in deviation. Where burst output signals are not modulated in frequency, there is generated a formant at a 2 kHz frequency region, and the frequency spectrum presents valleys on both sides of said region, namely, renders the Q of the formant signal much sharper. However, some musical tones or speech sounds contain such components whose simulation should be effected using a formant having a small Q value, or a relatively plain formant pattern. The embodiment of FIG. 12 is effective in such case.

In this embodiment, output signals from the fundamental frequency oscillator **91** are shaped into a saw-tooth wave whose voltage linearly varies with time. Accordingly, frequency components involved in frequency-modulated output burst signals are substantially uniform over the modulated frequency region. Not only the saw-tooth wave, but sine or rectangular wave may be used in producing input signals to modulate the voltage controlled variable frequency oscillator **92**. Also burst output signals will have the same effect, whether they assume a sine, rectangular or triangular wave.

In the embodiment of FIG. 12, output signals from the fundamental frequency oscillator **91** operated with a frequency period T_0 shown in FIG. 15A may be so shaped by the wave shaper **93** as to assume, for example, a two-stepped wave form presenting two voltage values V_A and V_B illustrated in FIG. 15B. Where the voltage controlled variable frequency oscillator **92** is supplied with input consisting of such shaped output signals whose voltage has different values, then it will be apparent that burst output signals from said oscillator **92** include instantaneous frequencies f_{2A} and f_{2B} corresponding to the different voltage values of control input signals. Such burst output signals will assume a wave form shown in FIG. 15C. The frequency spectrum of said burst output signals comprises, as shown in FIG. 16, two formants, the frequencies of which are f_{2A} and f_{2B}, respectively. Depending on the voltage wave form of control input signals supplied to the voltage controlled variable frequency oscillator **92**, a single formant frequency oscillator can generate a plurality of formants. It will be understood that where the voltage used has, for example, a three-stepped wave form, then there will be produced three formants by a single formant frequency oscillator.

We claim

1. A sound generating system comprising:
fundamental frequency signal generating means for generating signals of a fundamental frequency defining the pitch of sounds to be synthesized; and
at least one formant frequency signal generating means connected to said fundamental frequency signal generating means for producing signals of formant frequency associated with said sounds to be synthesized and being higher in frequency than said fundamental frequency, said formant frequency signal generating means starting its output generation in synchronism with output signals from said fundamental frequency signal generating means, and stopping its output generation at predetermined time during the period of said fundamental frequency signal to produce at the output of said formant frequency signal generating means signals including a component corresponding to said fundamental frequency for defining the pitch of said sound to be synthesized and harmonic components of said fundamental frequency component forming at least one formant included in said sounds to be synthesized.

2. A sound generating system according to claim 1 further comprising means for controlling the frequency of at least one of said fundamental frequency signal generating means and said formant frequency signal generating means.

3. A sound generating system according to claim 2 wherein said means for controlling the frequency comprises means for generating a control voltage signal of a low frequency to control said at least one signal generating means repeatedly.

4. A sound generating system according to claim 2 wherein said means for controlling the frequency comprises manually operable control means; and means for producing a transient control voltage signal in response to the operation of said manually operable control means to control said at least one signal generating means transiently.

5. A sound generating system according to claim 4 wherein said manually operated means includes the keyboard of an electronic musical instrument, and wherein the transient control voltage signal is generated in response to depression of a key of said keyboard.

6. A sound generating system according to claim 1 comprising a monostable multivibrator, which is controllable in its output pulse width, connected between said fundamental and formant frequency signal generating means; and means connected to said monostable multivibrator for generating a multivibrator output pulse control signal of a low frequency to control repeatedly the duration of said formant frequency signals from said formant frequency signal generating means responsive to said output pulses of said monostable multivibrator.

7. A sound generating system according to claim 1 comprising manually operable control means; a monostable multivibrator, which is controllable in its output pulse width, connected between said fundamental and formant frequency signal generating means; and means coupled to said manually operated control means and to said monostable multivibrator for generating a transient multivibrator output pulse width control signal in response to the operation of said manually operable control means to control transiently the duration of said formant frequency signals from said formant frequency signal generating means responsive to said output pulses of said monostable multivibrator.

8. A sound generating system according to claim 1 wherein said at least one formant frequency signal generating means includes an oscillator, the oscillations of which are started in synchronism with output signals from said fundamental frequency signal generating means.

9. A sound generating system comprising:
first generating means for generating signals having a frequency equal to an integral multiple of a fundamental frequency defining the pitch of sounds to be synthesized;
divider means connected to said generating means for producing signals of said fundamental frequency;
first formant signal generating means connected to said first generating means for generating signals of high formant frequency associated with said sounds to be synthesized which is higher in frequency than said fundamental frequency, said first formant signal generating means starting its output generation in synchronism with output signals from said first generating means, and stopping its output generation at a predetermined time during the period of said signals having the frequency equal to the integral multiple of said fundamental frequency;
second formant signal generating means connected to said divider means for producing formant frequency signals associated with said sounds to be synthesized which are lower in frequency than said high formant frequency and higher in frequency than said fundamental frequency, said second formant signal generating means starting its output generation in synchronism with output signals from said divider means, and stopping its output generation at a predetermined time during the period of said fundamental frequency signals; and
means for mixing output signals from first and second formant signal generating means to produce at the output of said mixing means signals including a component corresponding to said fundamental frequency for defining the pitch of sounds to be synthesized and harmonic components of said fundamental frequency component forming formants included in said sounds to be synthesized.

10. A sound generating system comprising:
fundamental frequency signal generating means for generating signals of a fundamental frequency defining the pitch of sounds to be synthesized;
formant frequency signal generating means including a voltage controlled variable frequency oscillator means connected to said fundamental frequency signal generating means for producing signals of formant frequency associated with sounds to be synthesized which is higher in frequency than said fundamental frequency, said formant frequency signal generating means starting its oscillation in synchronism with output signals from said fundamental frequency signal generating means, and stopping its oscillation at a predetermined time during the period of said fundamental frequency signal; and

means connected to said fundamental frequency signal generating means for shaping the wave form of output signals from said fundamental frequency signal generating means and supplying the shaped output signals to said voltage controlled variable frequency oscillator means to control the frequency thereof.

11. A sound generating system according to claim 10 wherein the output of said shaping means is a saw-tooth wave whose voltage varies, said saw-tooth wave varying the frequency of output signals from said voltage controlled variable frequency oscillator means.

12. A sound generating system according to claim 10 wherein the output of said shaping means is a stepped wave whose voltage varies in a step-wise manner, said stepped wave varying the frequency of output signals from said voltage controlled variable frequency oscillator means, thereby producing a plurality of formants of different frequencies.

13. A sound generating system according to claim 9 wherein said first and second formant frequency signal generating means include an oscillator generating oscillating output signals.

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