KEYBOARD TYPE ELECTRONIC MUSICAL INSTRUMENT

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ABSTRACT OF THE DISCLOSURE

An electronic musical instrument of keyboard type which has (1) a signal generating system composed of twelve tone series of signal sources for generating signals of pitches corresponding to the equal tempered musical scale, (2) a key switch system for switching tone signals to an output system by depressed keys on a keyboard, (3) the output system which converts them to acoustic tones, and (4) a difference-signal system which is included in the signal generating system and which comprises nineteen difference-signal generators for producing nineteen difference-signal in a low frequency range in such a way that (a) each of lower seven series of the twelve tone series has a pair of difference-signal generators, one of which produces a difference-signal as the lowest signal of each of lower seven series, and the other of which produces a difference-signal which is the second lowest signal of each of lower seven series, (b) each of upper five series of the twelve tone series has a single difference-signal generator which produces a difference-signal as the lowest signal of each of upper five series, and (c) each of nineteen difference-signal generators mixes two signals of signal sources, one signal in octave relation and the other signal in non-octave relation to a difference-signal to be produced by a difference-signal generator.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of our U.S. application Serial No. 427,621 filed Jan. 25, 1965, now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates generally to an electronic musical instrument of keyboard type, and more particularly to an electronic musical instrument having, in addition to normal signals for producing musical tone signals, two kinds of difference-signals, one of which is made by mixing two signals in a pitch interval of musical perfect fifth, i.e., two signals in frequency ratio of about 2:3, the other of which is made by mixing two signals in a pitch interval of musical perfect fourth, i.e., two signals in frequency ratio of about 3:4. Each of said two kinds of difference-signals has a frequency of the difference between two frequencies of said two signals. (The pitch intervals of "musical perfect fifth" and "musical perfect fourth" are defined in the musical terminology.)

DESCRIPTION OF THE PRIOR ART

In a conventional electronic musical instrument of keyboard type, one kind of difference-signal has been used. Such kind of difference-signal is made by mixing two signals in a pitch interval of musical perfect fifth, i.e., in frequency ratio of 2:3. This kind of difference-signal will be hereinafter referred to, for convenience, as a perfect fifth type difference-signal. Since the perfect fifth type difference-signal is lower in pitch by one octave than the lower one of the two mixed signals, such perfect fifth type difference-signal is only used as the lowest signal of each of twelve tone series of tone signals, i.e., C, C#(1), D, D#, E, F, F#, G, G#, A, A#, and B tone series of tone signals.

The nonlinearity of amplifiers, speakers, human ears or nonlinear circuits is responsible for producing difference-signal having a difference frequency between two frequencies of two signals. In view of such a fact, a certain kind of conventional pipe organ has partly had the perfect fifth type difference tones (signals) as tones of the pedal keyboard, and a certain kind of conventional electronic organ has also had the perfect fifth type difference-signals as tone signals of the pedal keyboard.

These conventional difference signals are of turbid tone color and different in tone color from the normal signals derived directly from signal sources such as oscillators and frequency divider circuits. Therefore, the conventional difference signals have been only used as tone signals of the pedal keyboard or not used as tone signals of the manual keyboard.

SUMMARY OF THE INVENTION

An object of the invention is to provide an electronic musical instrument characterized by a tone signal generating system for generating signals which include normal signals and two kinds of difference-signals, each of said signals having an individual pitch different from each other.

Another object of the invention is to provide a difference-signal generator for producing a novel difference-signal which has no disadvantage of producing turbid tone color which is similar, in tone color, to the normal signal.

A further object of the invention is to provide difference-signals which are of a desirable tone color and are used satisfactorily as tone signals of the manual keyboard.

The invention will be obvious from the following detailed description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a basic circuit diagram of a tone signal generating system which produces normal signals and two kinds of difference signals in accordance with the invention;

FIG. 2 is an electrical diagram of means for generating a conventional difference-signal;

FIG. 3 and FIG. 4 are electrical circuits according to the invention capable of eliminating the turbid and undesirable tone color of the conventional difference-signal;

FIG. 5 is a circuit diagram of a nonlinear circuit for producing a difference-signal; and

FIG. 6 is a basic circuit diagram of a modified embodiment of a tone signal generating system in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before going into a detailed description, it is pointed out that the explanation set forth hereinafter will be simplified as much as possible to provide an easy understanding of the embodiments and the scope of the invention. The number of signal sources, keyswitches and resistors, etc. will be greatly reduced by way of explanation. As the practical matter, of course, the number of different kinds of tones should be at least twelve
so as to ensure a complete musical scale comprising musical tones C, C♯, D, D♯, E, F, F♯, G, G♯, A, A♯ and B. Although the explanation set forth hereinafter will be limited to certain characteristic parts of an electronic musical instrument in a signal source with the invention, the other parts will be easily understood therefrom.

Referring to FIG. 1, normal signal sources 101 to 119 necessary for a conventional signal generating system are shown for easy understanding of the present invention. Normal signals are generated by normal signal sources 191, 193, 195, 197, 199 and 201. Fourth and sixteenth oscillators and frequency dividers and two kinds of difference-signals are generated by two kinds of difference-signal generators 271 to 277, as a first kind, and 278 to 289, as a second kind. Each of the first kind of difference-signal generators 271 to 277 generates a difference-signal by mixing two signals in a pitch interval of musical perfect fourth, i.e., two signals in frequency ratio of about 3:4. Each of the second kind of difference-signal generators 278 to 289 generates a difference-signal by mixing two signals in a pitch interval of musical perfect fifth, i.e., in frequency ratio of about 2:3. In such an arrangement, according to the invention, there is no need to employ the normal signal sources 101 to 119 for generating nineteen normal signals of musical scale in a low frequency range. According to the tone signal generating system of the invention, nineteen tone signals of the musical scale in a low frequency range are made of nineteen difference-signal tones generated by the two kinds of difference-signal generators 271 to 277 and 278 to 289.

In the detailed description to be made hereinafter, the tones corresponding to the musical scale are designated in order of pitch from the lowest tone as follows: C₁, C₂, D₁, D₂, E₁, F₁, F♯₁, G₁, G♯₁, A₁, A♯₁, B₁, C₂, C♯₂, C₃, C₄, C₅, D₂, D₃, D₄, D₅, E₂, E₃, F₂, F₃, F₄, G₂, G₃, G₄, G₅, A₂, A₃, A₄, A₅, B₂, B₃, B₄, C₃, C₄, C₅, C₆, . . .

Signal sources 190, 191, 192, 193, 194, 195, 196, 197, 198, and 199 generate signals of G₄, G₅, A₂, A₃, C₆, D₇, D₈, F₄, F₅, G₂, and G₆ tones, respectively, and are tuned in accordance with the equal temperament.

In the C-series of tone signals C₁, C₂, C₃, . . ., two kinds of difference-signal generators 271 and 273 are employed without using the two signal sources 101 and 113. The difference-signal generator 271 produces a difference-signal of C₁ by mixing the two signals G₂ (196.0 Hz) and C₃ (261.7 Hz) derived from the signal sources 190 and 200. The frequency ratio of about 3:4, through resistors 238 and 239, respectively. The difference-signal of C₁ (65.7 Hz) successively enters a keyswitch 220. The other difference-signal generator 283 produces a difference-signal of C₃ by mixing the two signals G₄ (261.7 Hz) and G₅ (329.2 Hz) in a pitch interval of perfect fifth, i.e., in frequency ratio of about 2:3, through resistors 250 and 251, respectively. The difference-signal of C₃ (130.3 Hz) successively enters a keyswitch 226.

The former type difference-signal will hereinafter be referred to, for convenience, as a perfect fourth type difference-signal. Since the perfect fourth type difference-signal C₁ is lower in pitch by one octave than the lower signal G₂ of the two mixed signals G₂ and C₃ of the signal sources 190 and 193, the perfect fourth type difference-signal C₁ is used as the lowest signal of the C-series of signals. The signal source 191 which will hereinafter be referred to as a perfect fifth type difference-signal, is lower in pitch by one octave than the lower signal C₃ of the two mixed signals C₃ and G₄ of the signal sources 193 and 198, and is used as the second lowest signal of the C-series. Therefore, there is no need to use the signal sources 101 and 113 as of C-series of normal signal sources 101, 113, 193 . . .

A signal C₃ generated by the signal sources 193 is fed to a keyswitch 231 through a resistor 257 so as to form the tone signal C₄. Higher tone signals C₅, C₆ (not shown) . . . of C-series are formed in the same way as that of the tone signal C₃. Thus all C-series tone signals are completed.

Similarly, also for tone signals of C♯-series, D-series, D♯-series, E-series and F-series, two kinds of difference-signal generators are employed in each series, without using the lowest two signal sources.

In the F-series of tone signals F₄, F₅, and F₆ . . . two kinds of difference-signal generators 277 and 289 are also employed, similarly to the C-series, C♯-series, D-series, D♯-series, E-series and F-series, without using the lowest two signal sources 107 and 119. The difference-signal generator 277 produces a difference-signal of F₄ by mixing two signals C₄ (277.2 Hz) and F₅ (370.0 Hz) derived from the signal sources 194 and 197 in a pitch interval of perfect fourth through resistors 244 and 245, respectively. The difference-signal of F₅ (92.8 Hz) enters a keyswitch 223. The other difference-signal generator 289 produces a difference-signal of F₆ by mixing two signals F₆ (370.0 Hz) and F₇ (554.4 Hz) derived from the signal sources 197 and 199 in a pitch interval of perfect fifth through resistors 253 and 255, respectively. The difference-signal of F₇ (184.4 Hz) enters a keyswitch 227. The signal F₈ generated by the signal sources 197 is fed to a keyswitch 235 through resistor 261 so as to form a tone signal F₉. Higher tone signals F₁₀, F₁₁ (not shown) . . . of F-series are formed in the same way as that of the tone signal F₇. Thus, all F-series tone signals are completed.

Therefore, for tone signals of the lower seven series, namely the C-series, C♯-series, D-series, D♯-series, E-series, F-series and F♯-series, a pair of difference-signal generators, i.e., a perfect fourth type difference-signal generator and a perfect fifth type difference-signal generator are employed in each series, without using the lowest two signal sources of said each series. Fourteen signal sources 101 to 107 and 110 to 119 of the lower seven series are saved by using seven perfect fourth type difference-signal generators 271 to 277 and seven perfect fifth type difference-signal generators 283 to 289.

In the G-series of tone signals, G₃, G₄, G₅, . . ., a kind of difference-signal generator 278 is employed without using the lowest signal source 108 of the G-series. The difference-signal generator 278 produces a difference signal of G₃ by mixing two signals G₂ (196.0 Hz) and D₃ (293.7 Hz) derived from the signal sources 190 and 195 in a pitch interval of perfect fifth through resistors 248 and 247, respectively. The difference-signal of G₄ (297.7 Hz) successively enters a keyswitch 224. The signal G₅ generated by the signal source 195 is fed to a keyswitch 236 through resistor 262 so as to form a tone signal G₆. Higher tone signals G₇, G₈, G₉ (not shown) . . . of the G-series are formed in the same way as those of the tone signals G₃ and G₄. Thus, all G-series tone signals are completed.

Similarly, for tone signals of the G♯-series, A-series, A♯-series, B-series and B♯-series, one kind of difference signal generator is employed in each series without using the lowest signal source.

Therefore, for tone signals of the upper five series, namely G-series, G♯-series, A-series, A♯-series and B-series, a single different-signal generator, i.e., a perfect fifth type difference-signal generator, is employed in each series without using the lowest signal source of each series. Five signal sources 108 to 112 of the upper five series are saved by employing five perfect fifth type difference-signal generators 278 to 282 (not shown).

A perfect fourth type difference-signal generator may be substituted for a perfect fifth type difference-signal generator. That is to say, for example, the difference signal G₁ is produced either by the perfect fifth type difference-signal generator 278 having two signals G₂ and
and a signal source 202 generates a signal having a frequency of 2n Hz. A signal at a frequency of 3n Hz. and a signal at a frequency of 2n Hz. are fed to an output terminal 212 through resistors 210 and 211, respectively, so as to form a mixed signal. The mixed signal derived from the output terminal 212 is converted by nonlinearity, such as nonlinearity of amplifiers, speakers, human ears or nonlinear circuits, into a difference-signal of a difference-frequency n Hz, which is the difference frequency between 3n Hz. of the signal of the signal source 201 and 2n Hz. of the signal of the signal source 202.

When these signal source 201 and 202 are precisely tuned according to the equal temperament, the frequency of the signal generated by the signal source 202 is 2n Hz. (for example, G₂ 196.0 Hz. = 2 × 98.0 Hz.), but the frequency of the signal generated by the signal source 201 is 3n Hz. (for example, D₂ 293.7 Hz. = 3 × 97.9 Hz.) which is slightly lower than 3n Hz. (for example, 3 × 98.0 Hz.) In other words, the frequency 3n' deviates slightly from an exact frequency 3n. Therefore, the signal having 3n' has harmonics 5n', 6n', 7n', 12n', ... while the signal having 2n having harmonics 4n, 6n, 8n, ... For convenience, the frequency n' (for example, 97.9 Hz.) is defined to be smaller by a very little frequency Δn (for example, 0.1 Hz.) than the frequency n (for example, 98.0 Hz.), namely n' = n − Δn.

Harmonics of the difference signal are produced by the harmonics of the two signals, namely 3n', 6n', 9n', 12n', ... so that the harmonics of the difference signal include difference frequency components n'' = (3n' − 2n), 2n'' = (6n' − 4n), 3n''' = (9n' − 6n), 4n'''' = (12n' − 8n), ... The frequency n'' is smaller by 3Δn from n', namely n'' = n − 3Δn, because 3n' = 3(n − Δn), n''' = 3(n − Δ)n − 2n'' = n − 3Δn.

Considering these harmonics and difference frequency components, therefore, the frequency spectrum of the difference signal is constituted by n'' = (2n, 2n''), (3n', 3n'''), (4n, 4n'''), (5n'', 6n'''), (6n, 6n'''), (6n', 6n''') ... A difference signal having such a complicated frequency spectrum is greatly different in tone color from a signal having a simple frequency spectrum of n, 2n, 3n, 4n, 5n, 6n ... which would have been derived directly from a signal source. Frequency components 2n, (3n'), 4n, 5n', 6n' ... which are slightly deviated from harmonics 2n, 3n, 4n, 5n, 6n ... make the difference signal of turbid and undesirable tone color. This is the reason why tone signals except pedal tone signals have not been composed of conventional difference signals. Pedal tone signals may be different in tone color from tone signals of manual keyboards. Pedal tone signals are usually careless about a turbid tone color.

Referring to FIG. 3, signal sources 201 and 202 are tuned according to the equal temperament, and, as an example, the signal source 201 generates a signal having a frequency of 3n' and the signal source 202 generates a signal having a frequency of 2n. Consequently, the signal generated by the signal source 201 has a frequency spectrum of 3n', 6n', 9n', 12n' ... and the signal generated by the signal source 202 has a frequency spectrum of 2n, 4n, 6n, 8n ... These two signals are mixed and fed to a nonlinear circuit 205 through resistors 203 and 204, respectively, so as to form a difference signal. The difference signal derived from the nonlinear circuit 205 has frequency components n'', (2n, 2n''), (3n', 3n'''), (4n, 4n'''), (5n'', 6n, 6n''') ... and is fed to a low pass filter 206 to weaken or eliminate overtone frequency components (2n, 2n''), (3n', 3n'''), (4n, 4n'''), (5n'', 6n, 6n''') (6n, 6n', 6n'''') ... are substantially removed.

Thus, the difference signal derived from the low pass filter 206 has the lowest frequency component n'' of a relatively large amplitude, and the overtone frequency components (2n, 2n''), (3n', 3n'''), (4n, 4n'''), (5n'', 6n, 6n''') (6n, 6n', 6n'''') ... are substantially removed.

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(196.0 Hz.) and D₂ (293.7 Hz.) of the signal sources 190 and 195 mixed together therein or by a perfect fourth type difference-signal generator in which two signals D₂ (293.7 Hz.) and G₃ (392.0 Hz.) of the signal sources 190 and 195 are mixed together therein, but can not be produced by a perfect fifth type difference-signal generator in which two signals C₂ (196.0 Hz.) and G₃ (261.7 Hz.) of the signal sources 190 and 193 are mixed together therein, because the signal C₂ (130.8 Hz.) of the signal source 113 does not exist actually in the signal generating system of FIG. 1.

Consequently, for twelve series of signal sources, nineteen signal sources 101, 102, 103 ... 118 and 119 are saved by using nineteen difference-signal generators 271, 272, 273 ... 289 in a low frequency range. The nineteen difference-signal generators act as nineteen signal sources such as oscillators and frequency dividers.

Two signals derived from respective keyswitches 220, 221, 222 ... are fed to an output system (not shown), where the tone signals are amplified by an amplifier (not shown) and converted into acoustic tones by electro-acoustic translating means (not shown) such as a speaker.

According to the principle of the invention as explained with reference to FIG. 1, for example, in an electronic musical instrument having sixty-one keys on the manual keyboard thereof, sixty-one tone signals can be composed partly of forty-two normal signals generated directly by forty-two signal sources in a high frequency range and partly of nineteen difference-signal-generators generated indirectly by sixteen pairs of signals of the forty-two signal sources through nineteen difference-signal generators. Therefore, the forty-two signal sources generate sixty-one tone signals by using the nineteen difference-signal-generators as shown in FIG. 1. It will be easily understood that the difference-signal system of FIG. 1 is effectively applicable also to an electronic musical instrument having two or more manual keyboards.

In general, a conventional tone signal generating system comprises oscillators and frequency dividers. The frequency dividers usually employ flip-flop circuits, each of which has two transistors or two vacuum tubes. According to the principle of the invention, therefore, nineteen frequency dividers are replaced by the difference-signal system which comprises the nineteen difference-signal generators. That is to say, thirty-eight transistors or thirty-eight vacuum tubes are saved by virtue of the difference-signal system. Thus, the principle of the invention makes it possible to construct an electronic musical instrument at low cost by employing the difference-signal system.

When the pitches of the difference-signal described hereinbefore are compared with the pitches of signals which would have been obtained directly from the signal sources tuned in accordance with the equal tempered scale, each pitch of the difference-signal deviates very slightly from each pitch of the signals corresponding to the equal tempered musical scale. For example, 65.7 Hz. and 97.7 Hz. of the difference-signals C₃ and G₃ respectively, deviate very slightly from 65.4 Hz. and 98.0 Hz. of the tone signals C₃ and G₃ corresponding to the equal temperament. But the deviated difference-signals can be applied either without hindrance, to the tone signal generating system of the electronic musical instrument according to the invention.

The following description with reference to FIGS. 2, 3, 4 and 5 will explain the details of each difference-signal generator shown in FIG. 1.

Referring to FIG. 2, as an example, a signal source 201 generates a signal having a frequency of 3n Hz.

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The difference signal derived from the low pass filter 206 and the signal generated by the signal source 202 are fed to an output terminal 209 through resistors 207 and 208, respectively. Thus, a novel difference signal is obtained by a novel difference signal generator according to the invention. The difference signal generator produces a novel difference signal having a frequency spectrum $n''$, $2n''$, $4n''$, $6n''$, $8n''$, ... .

As a result, the novel difference signal produced by the novel difference signal generator including a low pass filter does not have a turbid and undesirable tone color, but has a natural tone color similar to a tone color of a signal which would have been generated directly by a signal source.

Referring to FIG. 4, two signals generated by signal sources 201 and 202 are the same as the two signals described with reference to FIG. 3. The signal generated by the signal source 201 has frequency components $3n'$, $6n'$, $9n'$, ... and is fed to a low pass filter 213 to weaken or eliminate overtone frequency component $6n'$, $9n'$, $12n'$, ... . Thus, the signal derived from the low pass filter 213 has the lowest component $3n'$ of a relatively large amplitude, and the overtone frequency components $6n'$, $9n'$, $12n'$, ... are substantially removed.

The signal derived from the low pass filter 213 has almost only the lowest frequency component $3n'$, while the signal generated by the signal source 202 has frequency components $2n$, $4n$, $6n$, $8n$, ... . These two signals are fed to an output terminal 216 through resistors 214 and 215, respectively, so as to form a mixed signal.

The mixed signal derived from the output terminal 216 is converted by nonlinearity, such as nonlinearity of a nonlinear circuit, into a difference signal of a difference frequency $n''$ which is the difference between $3n'$ corresponding to the frequency component of the signal derived from the low pass filter 213 and $2n$ corresponding to the lowest frequency component of the signal generated by the signal source 202. Thus, another novel difference signal is obtained, and another difference signal generator is made according to the invention. Said another difference signal generator further produces another novel difference signal in a frequency spectrum of $n''$, $2n''$, $3n''$, $4n''$, ... which is similar to a normal frequency spectrum $n$, $2n$, $3n$, $4n$, ... . As a result, the difference signal produced by said another difference signal generator including a low pass filter does not have a turbid and undesirable tone color but has a desired tone color.

A difference signal generator including a low pass filter described hereinbefore will hereinafter be referred to, for convenience, as a low pass filter type difference signal generator.

The above description with reference to FIG. 3 and FIG. 4, has explained about novel difference signals, and has explained, as an example, a novel perfect fifth type difference-signal which is produced by mixing two signals in a pitch interval of perfect fifth, i.e., in frequency ratio of $2n:3n'$. One of the two signals has an exact frequency $2n$, which is essentially in octave relation to the frequency of the difference signal; while, the other of the two signals has a frequency deviated frequency $3n'$ which is in non-octave relation to the frequency of the difference signal. It is easily understood that another kind of novel difference-signal can be obtained by mixing two signals in a pitch interval of perfect fourth, i.e., in frequency ratio of $3n'$ which is in non-octave relation to the frequency of the difference-signal, the other of which has an exact frequency $4n$, which is essentially in octave relation to the frequency of the difference-signal. It is a matter of course for achieving said other kind of novel difference-signal, i.e., the novel perfect fourth type difference-signal that the signal source 201 generates a signal having a slightly deviated frequency $3n'$ and the signal source 202 generates a signal having an exact frequency $4n$ with reference to the low pass filter type difference signal generator shown in FIG. 3 or FIG. 4.

Since the low pass filter type difference signal generators can not only be employed as perfect fifth type difference-signal generators, but also be employed as perfect fourth type difference-signal generators, the low pass filter type difference-signal generators can be used similarly to the difference-signal generators mentioned with respect to FIG. 1. Therefore, successive tone signals of the manual key-board can be composed partly of novel difference-signal and partly of signals of signal sources. The successive tone signals are much alike in tone color.

Referring to FIG. 5, two signals in a pitch interval of perfect fourth or perfect fifth are mixed and fed together, through resistors 421 and 422, to a circuit comprising a parallel connection of resistor 423, a diode 424 and a capacitor 425 grounded at one end thereof and are converted into a difference-signal having an intensified fundamental pitch thereof. The difference-signal is derived through a resistor 428. The circuit is used as a nonlinear circuit adapted for the difference-signal generators as shown in FIGS. 1, 3 and 4.

Referring to FIG. 6, a generator system 301 includes signal sources 202, 252, 281, 282, 306, 307 and 308, a keyswitch system 302 of a manual keyboard includes key-switches 303, 304, 305, 306, 307 and 308 which correspond to tone signals C$\sharp$, D$\flat$, F$\sharp$, G$_2$, G, and C, respectively.

The pitch of the tone signal C$\sharp$ corresponding to the keyswitch 308 is determined by a perfect fourth type difference signal derived, through a resistor 358, from a perfect fourth type difference-signal generator 370 in which two signals G$\sharp$ and C$\sharp$ generated by signal sources 293 and 280 in a pitch interval of perfect fourth are mixed together through resistors 350 and 359, respectively.

The perfect fourth type difference signal C$\sharp$ is mixed with five additional signals, which are essentially in octave relation to said perfect fourth type difference-signal C$\sharp$, and four of which are signals C$\flat$, D$\flat$, E$\flat$, and F$\flat$ derived, through resistors 354, 353, 352 and 351, from the signal sources 280, 281, 282 and 283, respectively, and the remaining one of which is a perfect fifth type difference signal corresponding to C$\sharp$ derived, through a resistor 355, from a perfect fifth type difference-signal generator 371 in which two signals C$\flat$ and G$\flat$ generated by the signal sources 280 and 294 in a pitch interval of perfect fifth are mixed together through resistors 356 and 357, respectively, so that the tone signal C$\sharp$ becomes rich in tone color.

Tone signals C$\flat$, D$\flat$, E$\flat$, F$\flat$, and G$\flat$ (not shown) are composed of signals having the same relationship as that of the signals associated with the tone signal C$\flat$.

Similarly, the pitch of the tone signal F$\sharp$ corresponding to the keyswitch 307 is determined by a perfect fourth type difference-signal derived, through a resistor 348, from a perfect fourth type difference-signal generator 372 in which two signals C$\flat$ and F$\flat$ generated by the signal sources 284 and 290 in a pitch interval of perfect fourth are mixed together through resistors 350 and 349, respectively. The perfect fourth type difference-signal F$\flat$ is mixed with four additional signals, which are essentially in octave relation to said perfect fourth type difference-signal F$\flat$, and three of which are signals G$\flat$, F$\flat$, and E$\flat$ derived, through resistors 344, 343 and 342, from the signal sources 299, 291 and 292, respectively, and the remaining one of which is a perfect fifth type difference-signal corresponding to F$\flat$ derived, through a resistor 345, from a perfect fifth type difference-signal generator 374 in which two signals F$\flat$ and C$\flat$ generated by the signal sources 290 and 285 in a pitch interval of perfect fifth are mixed together through resistors 333 and 334, respectively, so that the tone signal F$\sharp$ becomes rich in tone color.

Each of the seven tone signals mentioned above, i.e., the tone signals C$\flat$, C$\natural$, D$\flat$, D$\natural$, E$\flat$, F$\flat$, and F$\natural$ is
composed of a perfect fourth type difference-signal and of several additional signals including signals from signal sources and a perfect fifth type difference-signal, the several additional signals being essentially in octave relation to said perfect fifth type difference-signal and acting as upper harmonics of said perfect fourth type difference-signal.

A pitch of the tone signal \( G_1 \) corresponding to the key-switch 306 is decided by a perfect fifth type difference-signal derived, through a resistor 339, from a perfect fifth type difference-signal generator 373 in which two signals \( G_2 \) and \( D_2 \) generated by the signal sources 293 and 287 in a pitch interval of perfect fifth are mixed together through resistors 340 and 341, respectively. The perfect fifth type difference-signal \( G_1 \) is mixed with four additional signals \( G_{9}, G_{3}, G_{4} \) and \( G_{5} \) derived, through resistors 338, 337, 336 and 335, from the signal sources 293, 294, 295 and 296, respectively, so that the tone signal \( G_1 \) becomes rich in tone color.

Tone signals \( C_{1}, A_{2}, A_{1}, B_{1}, C_{1}, C_{4}, D_{2}, D_{2}, E_{2} \) and \( F_{2} \) (not shown) are composed of signals having the same relationship as that of the signals concerning the tone signal \( G_1 \).

Similarly, a pitch of the tone signal \( F_{2} \) corresponding to the key-switch 305 is decided by a perfect fifth type difference-signal derived, through a resistor 332, from aforesaid perfect fifth type difference-signal generator 374. The perfect fifth type difference-signal generator 374 is commonly used for the tone signals \( F_{2} \) and \( F_{2} \). The perfect fifth type difference-signal \( F_{2} \) is mixed with three additional signals \( F_{9}, F_{4} \) and \( F_{2} \) derived, through resistors 331, 330 and 329, from the signal sources 290, 291 and 292, respectively, so that the tone signal \( F_{2} \) becomes rich in tone color.

Each of the twelve tone signals mentioned above, i.e., the tone signals \( G_1, G_{2}, A_{2}, A_{1}, B_{1}, C_{1}, C_{4}, D_{2}, D_{2}, E_{2}, F_{2} \) and \( F_{2} \) is composed of a perfect fifth type difference-signal and of several additional signals of signal sources, the several additional signals being essentially in octave relation to said perfect fifth type difference-signal and acting as upper harmonics of said perfect fifth type difference-signal.

As a practical matter, each of these difference signal generators 370, 371, 372 . . . is replaced with the low pass filter type difference-signal generator as shown in FIG. 3 or FIG. 4. The low pass filter type difference-signal generator has a nonlinear circuit such as the circuit comprising a parallel combination of a resistor 423, a diode 424 and a capacitor 425 shown in FIG. 5.

A pitch of the tone signal \( G_2 \) corresponding to the key-switch 304 is decided by the signal source 293 through a resistor 328. The signal \( G_2 \) is mixed with three additional signals \( G_{9}, G_{3} \) and \( G_{5} \) derived from the signal sources 296 through resistors 327, 332, 335, respectively, so that the tone signal \( G_2 \) becomes rich in tone color.

Similarly, a pitch of the tone signal \( G_{2} \) corresponding to the key-switch 305 is decided by a signal \( G_{2} \) derived from the signal source 297 through a resistor 324. The signal \( G_{2} \) is mixed with three additional signals \( G_{9}, G_{3} \) and \( G_{5} \) derived from the signal sources 298, 299 and 300 through the resistors 323, 322 and 321, respectively, so that the tone signal \( G_{2} \) becomes rich in tone color.

Each of the other tone signals \( A_{2}, A_{1}, B_{1}, C_{1}, C_{4}, D_{2}, D_{2}, E_{2} \) and \( F_{2} \) (not shown) is composed of a signal generated directly by a signal source and of several additional signals of signal sources, said several additional signals being in octave relation to said signal generated directly by a signal source and acting as upper harmonics of said signal generated directly by a signal source.

Several additional signals not only modify the tone color of a signal but also determine the tone color of the tone signal, because said additional signals act as upper harmonics, or as upper frequency components of the tone signal.

It is important that said several additional signals are mixed in each of the tone signals. If not so, there will be conspicuous differences in tone color among three kinds of tone signals, that is to say, among the first kind of tone signals \( G_1 \), \( F_{2} \), \( G_{2} \) having perfect fourth type difference-signals, the second kind of tone signals \( G_1 \), \( F_{2} \), \( G_{2} \) having perfect fifth type difference-signals and the third kind of tone signals \( G_9, G_3, A_2 \) having no difference-signals.

Tone colors of the tone signals characterized by having several additional signals become extremely similar to each other with the help of additional signals. Consequently, there are no conspicuous differences in tone color among the first kind of seven tone signals \( C_1, F_{2} \), \( F_{2} \) the second kind of twelve tone signals \( G_1 \), \( F_{2} \), \( G_{2} \) and the third kind of the remaining tone signals \( G_9, G_3, A_2 \). Therefore, nineteen difference-signals including two kinds of difference signals are used as tone signals of the manual keyboard without any hindrance for musical performance.

The concept of the novel difference signal system according to the invention can be applied not only to the manual keyboard of an electronic musical instrument, but also to the pedal keyboard of an electronic musical instrument in such a way that the pedal keyboard controls tone signals completed by the novel difference signal system.

It is believed that the invention and its advantages have been understood from the foregoing description and it is apparent that various changes may be made in the form, construction and arrangement of the parts without departing from the spirit and scope of the invention or sacrificing its advantages, the forms hereinbefore described and illustrated in the drawings being merely preferred embodiments thereof.

We claim:

1. An electronic musical instrument comprising in combination:
   (1) a signal generating system having twelve tone series of signal sources for generating signals of pitches corresponding to the signal tempered musical scale:
   (2) a keyswitch system which is coupled to said signal generating system and which has a plurality of key-switches capable of switching-on tone signals corresponding to depressed keys;
   (3) an output system which is coupled to said key-switch system and which includes an amplifier and electro-acoustic transducer.

2. The electronic musical instrument as defined in claim 1, wherein:
   (a) each of lower seven series of said twelve tone series has a pair of difference-signal generators, one of which produces a difference-signal as the lowest signal of said each of lower seven series, the other of which produces a difference-signal as the second lowest signal of said each of lower seven series;
   (b) and that each of upper five series of said twelve tone series has a single difference-signal generator which produces a difference-signal as the lowest signal of said each of upper five series, each of nineteen difference-signal generators mixing two signals of signal sources, one of which is essentially in octave relation to a difference-signal to be produced by said each of nineteen difference-signal generators, the other of which is in non-octave relation to said difference-signal to be produced by said each of nineteen difference-signal generators.
duces a difference-signal by mixing two signals of signal sources in a pitch interval of musical perfect fourth, said the other of a pair of difference-signal generators produces a difference signal by mixing two signals of signal sources in a pitch interval of musical perfect fifth, and said single difference-signal generator produces a difference-signal by mixing two signals of signal sources in a pitch interval of musical perfect fifth.

3. The electronic musical instrument as defined in claim 1, wherein each of said nineteen difference-signals is mixed with a plurality of additional signals which are essentially in octave relation to said each of said nineteen difference-signals and act as upper harmonics of said each of said nineteen difference-signals.

4. The electronic musical instrument as defined in claim 3, wherein:

said plurality of additional signals include at least a plurality of signals of said signal sources.

5. The electronic musical instrument as defined in claim 3, wherein:

said plurality of additional signals include at least a plurality of signals of said signal sources and one of said nineteen difference-signals.

6. A difference-signal generator adapted for an electronic musical instrument of keyboard type comprising in combination:

(1) a nonlinear circuit for generating a difference-signal by mixing two signals of pitches corresponding to the equal tempered musical scale, one of said two signals being a signal essentially in octave relation to said difference-signal, the other of said two signals being a signal in non-octave relation to said difference-signal,

(2) a low pass filter for weakening said difference-signal in the overtone frequency components thereof, and

(3) means for mixing the weakened difference-signal with said signal essentially in octave relation to said difference-signal.

7. The difference-signal generator as defined in claim 6, wherein said two signals are in a pitch interval of musical perfect fifth, said one of said two signals being a signal in an exact frequency 2n Hz, said the other of said two signals being a signal in a slightly deviated frequency 3n Hz.

8. The difference-signal generator as defined in claim 6, wherein said two signals are in a pitch interval of musical perfect fourth, said one of said two signals being a signal in an exact frequency 4n Hz, said the other of two signals being a signal in a slightly deviated frequency 3n Hz.

9. A difference-signal generator adapted for an electronic musical instrument of keyboard type comprising in combination:

(1) a low pass filter for weakening the overtone frequency component of a signal which is in non-octave relation to a difference-signal to be produced by said difference-signal generator, and

(2) means for mixing said weakened signal in non-octave relation to said difference-signal with a signal essentially in octave relation to said difference-signal, said signal in non-octave relation to said difference-signal and said signal essentially in octave relation to said difference-signal having pitches corresponding to the equal tempered musical scale.

10. The difference-signal generator as defined in claim 9, wherein said signal in non-octave relation to said difference-signal and said signal essentially in octave relation to said difference-signal are in a pitch interval of musical perfect fifth, said signal in non-octave relation to said difference-signal being a signal in a slightly deviated frequency 3n Hz, said signal essentially in octave relation to said difference-signal being a signal in an exact frequency 2n Hz.

11. The difference-signal generator as defined in claim 9, wherein said signal in non-octave relation to said difference-signal and said signal essentially in octave relation to said difference-signal are in a pitch interval of musical perfect fourth, said signal in non-octave relation to said difference-signal being a signal in a slightly deviated frequency 3n Hz, said signal essentially in octave relation to said difference-signal being a signal in an exact frequency 4n Hz.

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