A chorus generator for electronic musical instrument

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A generally rolling or moving chorus effect when such tones are reproduced simultaneously.

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ABSTRACT

An electronic musical instrument has a plurality of frequency synthesizers for separately generating the musical tones of each octave. Each of the frequency synthesizers is supplied with a train of clock pulses having a pulse repetition rate which is a multiple of the frequency of the highest musical tone generated by such frequency synthesizer. The pulse train applied to the frequency synthesizers for the highest octave is derived from a clock pulse source, and the pulse train applied to each of the other frequency synthesizers is derived from the pulse train supplied to the frequency synthesizer for the next higher octave, by dividing the pulse repetition rate thereof by a factor which differs slightly from two. As a result, corresponding musical tones of successive octaves are not locked in phase relationship but have frequencies which differ slightly from pure harmonics so as to present a generally rolling or moving chorus effect when such tones are reproduced simultaneously.

11 Claims, 5 Drawing Figures
CHORUS GENERATOR FOR ELECTRONIC MUSICAL INSTRUMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to electronic musical instruments and more particularly to electronic organs and the like in which the musical tones for a plurality of separate octaves are synthesized by frequency synthesizers.

2. The Prior Art

Electronic musical instruments typically employ a unit called a "top octave frequency synthesizer" for generating twelve output signals having frequencies corresponding to the musical tones of the highest octave of the instrument. Signals having frequencies corresponding to the musical tones of the second highest octave are derived from the outputs of the top octave synthesizer by dividing the pulse repetition rate of the outputs of the top octave synthesizer by a factor of 2 to derive a series of output signals having frequencies equal to half the frequencies of the output signals of the top octave synthesizer. Signals for the lower octaves are derived in a similar fashion. The relationship between corresponding signals of different octaves is exact, and the corresponding tones of each octave are locked into a precise phase relationship with each other. The frequencies of the tones produced by such an instrument are accurate and serve efficiently to produce musical sounds either singly or in combination. However, when two or more corresponding tones from separate octaves are sounded simultaneously, the result is somewhat different than that obtainable in sounding corresponding tones from separate octaves by means of a non-electronic musical instrument. When a non-electronic musical instrument is employed, the corresponding tones are not precise harmonics of each other, but differ slightly therefrom, producing a chorus effect. This difference manifests itself in a sound effect which may be referred to as a rolling or a moving chorus effect.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide a means for generating a rolling or moving chorus effect to musical tones simultaneously produced in an electronic musical instrument.

This and other objects and advantages of the present invention will become manifest upon an examination of the accompanying drawings and the following description.

One embodiment of the present invention employs a plurality of frequency synthesizers, one for each octave of musical tones to be generated in the instrument, a source of clock pulses having a pulse repetition rate which is a multiple of the highest frequency desired for said musical tones, the frequency synthesizer for the octave having the highest frequencies being connected to said source, and a plurality of frequency dividers connected in cascaded relationship for successively dividing the pulse repetition rate of said pulse train by a factor which differs slightly from 2, such frequency dividers being connected individually to the inputs of the frequency synthesizers for the lower octaves.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram of a chorus generator incorporating an illustrative embodiment of the present invention;

FIG. 2 illustrates a series of waveforms occurring during the operation of the apparatus of FIG. 1;

FIG. 3 is a functional block diagram of an alternative embodiment of the present invention;

FIG. 4 is a functional block diagram of yet another embodiment of the present invention; and

FIG. 5 illustrates a series of waveforms occurring during the operation of the apparatus of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a source 10 of clock pulses connected by a line 12 to a frequency synthesizer 14. The source 10 is conventional in electronic musical instruments, and the frequency synthesizer 14 is also conventional, and is preferably a type similar to the model number S2555/S2556 marketed by American Micro-Systems Inc. The Synthesizer 14 has twelve output lines 16 which are connected to the various keys and other circuits of the electronic musical instrument, in order to furnish the appropriate signals to the output system of the instrument. Output signals appearing on the twelve output lines 16 have frequencies corresponding to the twelve frequencies of the even tempered scale for the highest octave of the instrument. Conventionally, the frequency of the clock pulse source 10 is 2,00024 megahertz, and the frequencies of the outputs 16 vary from 8369.21 hertz to 7906.09 hertz, conforming to the C and B, respectively, of the octave having the highest frequencies, which are often referred to as C9 and B8. The output of the source 10 is illustrated by waveform A of FIG. 2.

The output of the source 10 is also connected by a line 18 to a flip-flop 20 which functions as a frequency divider, producing on an output line 22 a signal having a pulse repetition rate equal to half of that present on the line 18. The signal on the line 22 is illustrated by waveform B of FIG. 2. The line 22 is connected to one input of an exclusive OR gate 24, and the output of the exclusive OR gate 24 is connected by a line 26 to the input of a second frequency synthesizer 28. The frequency synthesizer 28 is provided for the second highest octave and produces, on 12 output lines 30, signals having frequencies ranging from B7 to C8, for the second highest octave of the instrument.

A second input is connected to the exclusive OR gate 24 over a line 32. The exclusive OR gate 24 operates in the conventional manner to provide a high level output on the line 26 if one and only one of the two input lines 22 and 32 is energized with a high level signal. Accordingly, the exclusive OR gate 24 functions to pass the pulses occurring on the input line 22 in unmodified form, as long as a low level signal is applied to the other input via the line 32. If a high level input is applied to the line 32, the exclusive OR gate functions to invert the signals appearing on the input line 22 and produces inverted pulses on the output line 26 in response to the pulses on the line 22. The function of the exclusive OR gate 24 is to cause the average pulse repetition rate of the pulse train applied to the output line 26 to differ slightly from the average pulse repetition rate of the pulse train appearing on the line 22. This is accom-
plished by causing the exclusive OR gate 24 to occasionally omit one of the pulses applied to its input on the line 22, from the pulse train appearing on the output line 26.

An oscillator 34 is provided to produce pulses at a relatively low pulse repetition rate on an output line 36. The line 36 is connected to the D input of a D type flip-flop 38, and the clock input of the flip-flop 38 is connected from the line 18, over a line 40. The flip-flop 38 passes the D input to the output coincidentally with a positive-going edge of the clock signal present on the line 40. The output of the flip-flop 38, supplied to the line 32, is illustrated by waveform C of FIG. 2, for a case in which a pulse is provided on the line 36 for each eleven cycles of the clock pulses produced by the source 10. In practice, the pulse repetition rate of the oscillator 34 is much lower than the rate of the source 10, and is preferably on the order of 2 percent or less of the pulse repetition rate produced by the source 10. However, a higher frequency has been illustrated in the waveforms of FIG. 2 in order to better illustrate the operation of the apparatus.

The output of the exclusive OR gate 24 supplied to the line 26 is illustrated in waveform D of FIG. 2. The state of the output on the line 26 is extended for an additional period equal to one-half cycle of the pulse train on the line 32, each time there is a change of level of the signal on the input line 32. Accordingly, for each two changes of level of the signal (i.e., one cycle) applied to the input line 32, a pulse is dropped from the output on the line 26, yielding a slightly lower pulse repetition rate on the output line 26 than would be the case if the repetition rate of the clock pulse signal on the line 18 were simply divided by 2. As a result, the frequency synthesizer 28 produces signals on the output lines 30 which differ in frequency from the corresponding output signals of the synthesizer 14 by a factor slightly different from 2, and the outputs on the lines 30 are, therefore, not locked in phase to the corresponding outputs on the lines 16.

The output line 22 of the flip-flop 20 is connected by way of a line 42 to the input of a flip-flop 44, which functions to divide the pulse repetition rate by 2 and to produce, on an output line 46, the pulse train illustrated in the waveform E of FIG. 2. The line 46 is connected to one input of an exclusive OR gate 48, which produces, on an output line 50, a pulse train connected to the input of a third frequency synthesizer 52 having 12 output lines 54 at which are produced signals having frequencies corresponding to the third highest octave of the musical instrument.

A second input for the exclusive OR gate 48 is connected from the output of a D type flip-flop 58 over a line 56. The D input of the flip-flop 58 is connected from an oscillator 60 over a line 62 and the clock input is connected from the line 42 over a line 64. The output of the flip-flop 58, which is connected to the line 56, produces a signal which causes the exclusive OR gate 58 to occasionally omit a pulse from the output produced on the line 56, in the same manner as has been described in connection with the exclusive OR gate 24. The waveform F1 of FIG. 2 illustrates a signal which is produced on the line 56 when the oscillator 60 operates at the same frequency and in phase synchronism therewith. The waveform F1 does not correspond exactly to the waveform C because the flip-flop 58 does not change its state until a positive-going signal is applied to the clock input over the line 64. The output on the line 50 which is produced when the waveform F1 is supplied to the input 56 is illustrated by waveform G1 of FIG. 2. The waveform G1 corresponds to the waveform E except that one pulse is omitted for each two changes in the level of the signal on the line 56, just as has been described above in connection with the exclusive OR gate 24.

When the oscillator 60 functions at a different frequency than the oscillator 34, but at a lower frequency, the operation is similar, except that fewer pulses are omitted. The waveform F2 of FIG. 2 illustrates a lower frequency signal resulting at the output of the flip-flop 58 when the oscillator produces pulses at a lower pulse repetition rate. The output of the exclusive OR gate 48 is, in that case, illustrated by the waveform G2 of FIG. 2, which has fewer pulses omitted over a given period of time than the waveform G1.

When the lines 36 and 62 are both connected to the same oscillator, the frequency at which pulses are omitted from the output on the lines 26 and 50 is the same. Accordingly, the deviation in frequency as a result of the pulse omissions is twice as large on the output line 50 as on the line 26. In order to maintain approximately the same ratio between the theoretically correct frequency supplied to the frequency synthesizers and the average pulse repetition rate which results after the omission of certain pulses, it is desirable to operate the oscillator 60 at a lower pulse repetition rate than the oscillator 34. In some cases it may be desirable to derive a pulse train to be connected to the line 62 by dividing the pulse repetition rate of the oscillator 34 by a factor of 2, in order to obtain a pulse repetition rate on the line 62 equal to half of that of the pulse train on the line 36. In that event, the oscillator 60 may be omitted. In most cases, however, it is preferable to employ variable frequency oscillators for the oscillators 34 and 60, so that they can be manually controlled independently, so as to allow the most pleasing musical effect.

The manual controls for such variable frequency oscillators are indicated by the diagrammatically illustrated controls 34a and 60a shown in FIG. 1. The apparatus of the present invention functions to produce a succession of harmonically related tones for each octave of the musical instrument each of which differ slightly from corresponding tones in other octaves by a factor slightly different from 2 or a power of 2. This produces a chorus effect, having a rolling or moving sound, when a plurality of corresponding tones are connected simultaneously to the output system of the instrument.

An alternative embodiment of the present invention is illustrated in FIG. 3. In this embodiment the several frequencies for each octave are derived in two separate frequency synthesizer units, which are driven by pulse trains having slightly different pulse repetition rates. In this way the frequencies produced by each pair of synthesizer units produce a chorus effect with each other. This is achieved by driving one of each pair of frequency synthesizer units with a first pulse train, and driving the other unit with a pulse train having a slightly different pulse repetition rate. The two different pulse trains are produced by means of the exclusive OR gate circuit described in connection with FIG. 1.

As in FIG. 1 a clock pulse generator 10 is provided and a chain of flip-flops connected in cascade, including flip-flops 20 and 44 are provided for successively halving the pulse repetition rate of the signal produced
The frequency synthesizer units 14a and 14b are provided for deriving the frequencies for the top octave. The synthesizer unit 14a is driven directly by the output pulses of the clock generator 10 over line 12, and the synthesizer unit 14b is clocked by the output pulses of an exclusive OR gate 70. A first input of the exclusive OR gate 70 is connected to the line 12, and the second input is connected over a line 72 to a source of a lower frequency signal.

In the embodiment of FIG. 3, this source is an output of the synthesizer unit 52b which produces output frequencies for the third highest octave.

The synthesizer units 28a and 28b, which are provided for the second highest octave, are driven by lines 74 and 76, respectively, which are connected with the output terminals of exclusive OR gates 78 and 80, respectively. A first input of each of the exclusive OR gates 78 and 80 is connected over the line 22 to the output of the flip-flop 20, and the second inputs of each of the exclusive OR gates 78 and 80 are derived from separate sources of low frequency signals over lines 82 and 84, respectively. In the embodiment of FIG. 3, these lines are connected to two separate outputs of the synthesizer unit 52a which is provided for the third highest octave.

In similar fashion exclusive OR gates 86 and 88 are provided for driving the synthesizer units 52a and 52b, and have a first input connected over a line 46 to the output of the flip-flop 44. The second input of the exclusive OR gate 88 is connected to a source of a low frequency signal which, in the embodiment of FIG. 3, is an output of the synthesizer unit 52b. The second input of the exclusive OR gate 86 is connected, in the embodiment of FIG. 3, to the output of a flip-flop (not shown) which is one of a chain of flip-flops connected in cascade with the flip-flops 20 and 44.

In every case, the first input of the exclusive OR gate is connected to an output of one of the flip-flops in the chain of flip-flops including the flip-flops 20 and 44, while the second input is connected to a different source of a low frequency signal. As illustrated in FIG. 3 this source may be an output of a frequency synthesizer unit either of a lower octave or a higher octave (or even the same octave) relative to the octave of the synthesizer unit driven by each particular exclusive OR gate. Alternatively, the second input of the exclusive OR gate may be derived from a low frequency signal produced by a flip-flop in the chain of cascaded flip-flops.

The selection of the source of signal for the second input of each exclusive OR gate is entirely within the discretion of the designer of the instrument and the sources are chosen to produce what the designer considers the optimum effect. As this is a highly personal judgement, it is likely that a variety of choices would be made by a number of designers. Moreover, if a set of selection switches is provided for the use of the player of the instrument, the choice of the second inputs may be placed within the control of the player of the instrument. In general, satisfactory results are obtained when the second inputs of the exclusive OR gates are connected to a variety of different sources, so that the chorus effect has a relatively random characteristic.

The flip-flops such as the flip-flops 38 and 58 of FIG. 1 are not required in the apparatus of FIG. 3 because the signals which are connected to the second inputs of the exclusive OR gates are in phase synchronism with the clock-pulses, as a result of the inherent operation of the frequency synthesizer units and the cascaded flip-flops. It is therefore not necessary to employ the flip-flops such as the D-flip-flops 38 and 58 of FIG. 1 in order to obtain synchronization of the signals applied to the various exclusive OR gates.

The embodiments of FIG. 1 and 3 both operate to omit pulses in response to a low frequency signal applied to the second inputs of the exclusive OR gates. It is, however, sometimes desirable to add additional pulses instead of omitting pulses, in order to slightly increase the frequency of the various outputs of the synthesizer units, instead of slightly decreasing them. In FIG. 4, apparatus for accomplishing that result is illustrated. The flip-flops 20 and 40 correspond to the similarly identified flip-flops in FIGS. 1 and 3 which function to derive sub harmonics of the pulse repetition rate of the clock pulse generator 10. An exclusive OR gate 90 has the first input connected over a line 22 with the output of the flip-flop 20. The signal on the line 22 is illustrated in waveform A of FIG. 5. The line 22 is connected to the clock input of a D-type flip-flop 92 by a line 94, and a source of a low frequency signal is applied to a terminal 96 and from there over a line 98 to the D-input of the flip-flop 92. The flip-flop 92 synchronizes its output, which appears on a line 97, with the pulses arriving over the line 22. A typical signal applied to the terminal 96 is illustrated by waveform B of FIG. 5 and an output of the flip-flop 92 is illustrated in waveform C of FIG. 5. Of course, if the signal applied to the terminal 96 is already synchronized with the signal on the line 22, as the outputs from the synthesizer units, for example, the D flip-flop may be omitted and the terminal 96 connected directly to the line 97.

The line 97 is connected to the input of a first monostable multivibrator 100, and the output of the monostable multivibrator 100 is connected to the input of a second monostable multivibrator 102. The output of the multivibrator 102 is connected over a line 104 to the second input of the exclusive OR gate 90. The periods of the two monostable units 100 and 102 are preferably approximately one-third of the duration of the pulses on the line 22, and the outputs of the monostable units 100 and 102 are respectively illustrated in waveforms D and E of FIG. 5.

Waveform F of FIG. 5 illustrates the output of the exclusive OR gate 90. The effect on the pulses on the line 22 is to break up single pulses of this pulse train into double pulses, by applying the short pulses of the waveform E to the second input of the exclusive OR gate 90 coincidentally with the mid-portion of one of the pulses supplied by the line 22. This, in effect, adds a pulse for each operation of the monostable multivibrator 102. This occurs at a rate dependent upon the frequency of the signal applied to the terminal 96.

If desired, the period of the monostable unit 102 may be made longer than 1/3 of a pulse length, but should be of a duration which insures that the trailing edge of the output pulse does not coincide with a leading or trailing edge of the waveform A of FIG. 5, or else a pulse would be omitted from the output of the exclusive OR gate 90 instead of being added, in response to the trailing edge of the multivibrator-produced pulses.

By using the apparatus of FIG. 4 to supply driving signals for some of the frequency synthesizer units, the average pulse repetition rate is increased slightly from the
nominal frequency for some octaves. This provides a maximum chorus effect among the several octaves, without a great departure from the nominal frequency values.

It may be desirable to provide one or both of the synthesizer units of one or more octaves with an input derived from cascaded flip-flops, which furnish pulse trains having a pulse repetition rates precisely equal to the nominal value, in order to maximize the chorus effect among all the octaves.

It will be obvious to those skilled in the art that certain modifications may be made in the embodiments described herein, without departing from the present invention. For example, in the apparatus of FIG. 1, the D flip-flops 38 and 58 may be replaced by monostable multivibrators, especially if the low frequency signals are derived from sources not in phase synchronization with the clock pulses applied to the first input of the exclusive OR gates. In such an arrangement, although occasionally one of the leading or trailing edges of the pulses applied to the second input of the exclusive OR gates may be synchronized with the clock signals, normally they do not coincide with the leading or trailing edges of the clock pulses so that pulses are added by operation of the exclusive OR gate in the same manner as has been described in connection with FIG. 4.

It is to be understood that less than all of the features of the invention herein described can be utilized to advantage, if desired, but that the preferred form of the invention is that which has been described.

Although various minor modifications might be suggested by those versed in the art, it should be understood that I wish to embody within the scope of the patent warranted hereon, all such embodiments as reasonably and properly come within the scope of my contribution to the art.

What is claimed is:

1. An electronic musical instrument, the combination comprising a pair of frequency synthesizers, a source of clock pulses connected to one of said frequency synthesizers, and frequency divider means connected with said source for dividing the pulse repetition rate of said clock pulses by a factor which differs slightly from 2, said frequency divider means being connected to another one of said frequency synthesizers.

2. Apparatus according to claim 1 including a third frequency synthesizer, and a second frequency divider means connected with the first frequency divider means for dividing the pulse repetition rate furnished by said first frequency divider circuit by a factor which differs slightly from 2, said second frequency divider means being connected to said second frequency synthesizer.

3. Apparatus according to claim 1 wherein said frequency divider means comprises a flip-flop for dividing the pulse repetition rate of said clock pulses by a factor of 2, an exclusive OR gate having one input connected to said flip-flop, an oscillator for generating a signal having a lower frequency than said clock pulses means for connecting, said oscillator with a second input of said exclusive OR gate for causing said exclusive OR gate to produce a train of pulses at its output having a pulse repetition rate which differs slightly from the output of said flip-flop.

4. Apparatus according to claim 3, including a D-type flip-flop having its D input connected to said oscillator and its clock input connected to said source, the output of said D-type flip-flop being connected to said second input of said exclusive OR gate.

5. Apparatus according to claim 2, wherein said first frequency divider means comprises a first flip-flop for dividing the pulse repetition rate of said clock pulses by a factor of 2, a first exclusive OR gate having one input connected to said first flip-flop, an oscillator for generating a signal having a lower frequency than said clock pulses, means for connecting said oscillator with a second input of said first exclusive OR gate, and said second frequency divider means comprises a second flip-flop having its input connected to the output of said first flip-flop for dividing the pulse repetition rate thereof by a factor of 2, a second exclusive OR gate having one input connected to said second flip-flop, and a second oscillator for generating a signal having a lower frequency than said clock pulses, means connecting said second oscillator (being connected) with a second input of said second exclusive OR gate.

6. Apparatus according to claim 5, wherein said first and second oscillators are manually adjustable variable frequency oscillators.

7. Apparatus according to claim 5, wherein the frequency of said second oscillator differs slightly from half that of said first oscillator.

8. A chorus generator for an electronic musical instrument comprising a frequency synthesizer for each octave of said instrument, a source of clock pulses directly connected to one of said frequency synthesizers, and circuit means connected to the remaining ones of said frequency synthesizers for supplying each of the remaining ones of said frequency synthesizers with a train of pulses, said trains of pulses having pulse repetition rates which are harmonically related approximately by powers of 2, and a plurality of manually adjustable oscillators connected with said circuit means for selecting the amount by which said pulse trains differ from being related by powers of 2.

9. Apparatus according to claim 1, wherein said frequency divider means includes deriving means for deriving a train of pulses having a pulse repetition rate which differs from said clock pulses by a factor of two, and means connected with said deriving means for periodically omitting pulses from said train.

10. Apparatus according to claim 1, wherein said frequency divider means includes deriving means for deriving a train of pulses having a pulse repetition rate which differs from said clock pulses by a factor of two, and means connected with said deriving means for periodically inserting additional pulses into said train.

11. Apparatus according to claim 10, wherein said last named means comprises a monostable multivibrator.
Notice of Adverse Decision in Interference,

In Interference No. 99,240, involving Patent No. 3,828,109, E. S. Morez, CHORUS GENERATOR FOR ELECTRONIC MUSICAL INSTRUMENT, final judgment adverse to the patentee was rendered Dec. 20, 1976, as to claims 1 and 9.

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