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VARIABLE TIME DELAY MULTIVIBRATORS
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4 Claims

ABSTRACT OF THE DISCLOSURE

A pulse generator having a stable state and a quasi-stable state, undergoing a time delay between triggering to the quasi-stable state and return to the stable state which depends on the time constant established by selected circuit elements and on the variation in bias voltage on an active element of the generator. Random variation of the bias voltage produces random pulse durations equivalent to frequency perturbation, but maintains the average frequency of the output pulses the same as the frequency of incoming trigger pulses.

BACKGROUND OF THE INVENTION

The present invention pertains in part to relaxation oscillators of the multivibrator type wherein the time period within which the device remains in a particular state is rendered variable by varying one or more operating parameters of the device, and in part to electronic musical instruments wherein such devices are used in the tone generating apparatus to randomize the phasing of the output tones.

As is well known, monostable or one-shot multivibrators are characterized by a stable operating state and a quasi-stable operating state, transition from the former to the latter being triggered by an external signal, usually a pulse or spike, termed a "trigger" or "set" pulse, whereas return transition to the "reset" state or condition (i.e. back to the stable state) occurs spontaneously after a fixed time interval, without the aid of an external signal. The device is often used to produce a pulse upon elapse of a fixed time interval following the transmission of a first pulse (the trigger) so as to effect a desired delay; hence it is commonly referred to as a delay multivibrator. Since the delay depends to a great extent on component values and types and/or on the magnitude of the bias voltages applied to the multivibrator, it is possible to preselect any desired delay period, within practical limits, to be introduced by the multivibrator.

The present invention has, as one of its objects, the provision of a monostable multivibrator whose delay period, i.e. interval during which the device remains in its quasi-stable state, varies in random fashion. More specifically, it is an object of the invention to provide a monostable multivibrator whose delay time is controlled by a source of randomly varying voltage to appropriately modulate the width or duration of output pulses emanating therefrom. It will be observed, then, that if the output pulse of the noise-controlled delay multivibrator is utilized to trigger the operation of some other device, such as a bistable multivibrator (flip-flop) the result is random perturbation or random triggering.

It is another object of the present invention to provide excitatory circuits for random perturbation of triggerable or switchable devices, i.e. devices which may be forced to undergo a transition from one state to another.

An application of the present invention resides, for example, in electronic musical instruments in general, and electronic organs in particular. Many electric organs utilize twelve basic tone generators or master oscillators for production of notes of either the highest or lowest

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octave of the organ. The output of each of these master oscillators is successively divided (or multiplied) to produce notes of the lower or higher octaves. The basic tone generators are typically continuously running, i.e., are functioning at all times, so that a note in any octave may be produced upon depression or actuation of the appropriate key.

Most electronic organs are designed to simulate or imitate the tones produced by a pipe organ. The vibrations emanating from the voice aperture of each resonant pipe of the pipe organ have a randomness of phase and are accompanied by a rush or whistle of air or wind, effects which are pleasing to the ear of the listener. On the other hand, electronic organs generally lack these effects and are often characterized by such preciseness of output as to present a synthetic sound.

It has been found that noise on the output voltage of the power supply for the tone generators can simulate the rushing sound of air through pipes of the conventional pipe organ. Such an expedient, however, is ineffective in the case of continuously running oscillators connected in divider or multiplier chains, because the same fluctuations are transferred throughout the divider or multiplier chain and hence fail to produce random phasing of the output tones.

SUMMARY OF THE INVENTION

According to one aspect of the invention, a noise controlled delay multivibrator comprises a pulse generator triggerable from a stable operating state to a quasi-stable state, returning to the stable state after a time delay depending on the time constant of the generator circuit and the instantaneous level of bias voltage on an active element of the generator. For output pulses of random duration but of average frequency corresponding to that of the trigger pulses applied to the pulse generator, the bias voltage level is controlled by the output of a noise source.

The present invention also provides in a frequency divider or multiplier chain for production of tones associated with octavely related notes, excitatory circuits for supplying random perturbation of each divider or multiplier, each excitatory circuit including a noise controlled delay multivibrator of the type mentioned briefly above, and each divider of the chain comprising, for example, a flip-flop which is triggered from one stable state to the other, and vice versa, by pulses generated by one of the delay multivibrators, and which in turn supplies trigger pulses to another delay multivibrator for excitation of the following flip-flop in the divider sequence or chain. Each delay multivibrator is set, i.e. triggered to its quasi-stable state, when the preceding flip-flop generates a positive-going pulse; and remains in the quasi-stable state for a period determined by the noise voltage present, the period therefore being randomly variable, after which the multivibrator is reset to its stable state. The time durations of successive pulses generated by each noise control delay multivibrator differ because of this randomness, being equivalent to frequency perturbation. The average frequency, however, remains unaltered. The delay perturbation of each delay multivibrator is transferred to the flip-flop under its control and so on through the chain, the uncertainty in the delay variations of successive delay multivibrators increasing by a factor equal or substantially equal to the division factor of the chain, provided the same or substantially the same amount of noise voltage is used for each delay multivibrator. This differs from the case in which a random fluctuation is initially derived and this fluctuation simply transferred through the chain, in which case there is no random phasing of the output of each divider. In accordance with the present invention, the randomness of the trigger for each flip-flop, and hence

of the output of the flip-flop, differs for each flip-flop in the chain while the uncertainty of the delay variations of successive delay multivibrators is a function of the dividing (or multiplying) factor of the chain.

It is therefore another object of the present invention to provide in an electric organ, frequency perturbation of tones developed from a continuously running master oscillator whose output frequency is successively divided to produce octavely related notes.

It is a further object of the present invention to provide an electronic organ having continuously running tone generators, the output tones of the organ being randomly phased by random excitation or perturbation of at least some of the tone generators.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of certain preferred embodiments thereof, especially when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of an electronic tube version of a monostable multivibrator incorporating principles of the present invention;

FIGURE 2 is a block diagram of a master oscillator-divider chain for generation of octavely related tones in an electronic organ, for example, using noise-controlled delay multivibrators in accordance with the present invention;

FIGURE 3 is a graph or chart illustrating certain of the waveforms generated by the components in the circuit of FIGURE 2, and helpful in explaining the timing for those components; and

FIGURE 4 is a schematic diagram of a solid state embodiment of a portion of the circuit of FIGURE 2, incorporating a transistorized version of a noise-controlled delay multivibrator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGURE 1, there is shown a cathode-coupled monostable or one-shot multivibrator of conventional form except in respect to certain structural and operational features in accordance with the present invention, as will be discussed in detail in the ensuing description. The circuit comprises a pair of vacuum tubes 15 and 20 (or two distinct tubes in a single envelope, as shown) having cathodes coupled by a common resistor 16 to ground, the plate of tube 15 coupled to the grid of tube 20 via a capacitor 19, and each of the tubes supplied from a common source of supply voltage, designated E_{BB} . The grid of tube 20 is also coupled to the supply voltage in a manner to be described presently.

Prior to receipt of a trigger pulse or positive-going step wave at terminal 10, tube 15 is cut off and tube 20 is conducting, by virtue of the DC bias voltage level on the grid of the former and the effectively clamped grid of the latter. This situation characterizes the stable operational state of the multivibrator.

A positive-going trigger pulse applied to terminal 10 is differentiated by low time constant RC (differentiator) network 12 comprising series capacitor 13 and shunt resistor 14, to provide a synchronizing pulse at the grid of tube 15 that renders the latter conductive. Consequently, the grid of tube 20 is driven highly negative relative to its cathode, and tube 20 is cut off. This is the situation characterizing the quasi-stable state of the delay multivibrator.

In the absence of noise generator 25, (i.e., a source of noise voltage) the multivibrator returns to its stable state when the voltage at the grid of tube 20, which rises exponentially at a rate determined primarily by the RC time constant, imposed by resistor 18 and capacitor 19, reaches a value slightly greater than the cutoff voltage for that tube as set in part by the supply voltage level E_{BB} .

The time within which this value of grid voltage is achieved, then, depends largely upon the value of the supply voltage for tube 20, or more precisely, upon the voltage level at the grid of the tube. If the supply voltage is fixed, variation of delay, i.e., adjustment of time duration of quasi-stable state, may be accomplished by appropriate adjustment of the DC bias voltage on the grid of tube 15 and by selection of values of the components determining the time constant for relaxation of the grid of tube 20 to a level slightly above the cutoff value.

According to one aspect of the present invention, noise source 25 is inserted between the grid of tube 20 and the source of supply voltage. The voltage at node or point 27 of the circuit is thus the algebraic sum of the supply voltage and the noise voltage, and undergoes random variation in either direction from the voltage level E_{BB} . For voltage levels at node 27 greater than E_{BB} , the time interval required for termination of the quasi-stable state is less than that which would occur if grid voltage were determined by E_{BB} alone, whereas for voltage levels less than E_{BB} the delay is greater. Since the noise output of source 25 consists of random fluctuations (for a "random noise" source), it will be apparent that the delay (time between set and reset of the multivibrator) also varies in a random fashion following application of each trigger pulse to the multivibrator. The output of the multivibrator, then, is a pulse whose width corresponds to the random time interval during which the multivibrator is in its quasi-stable state.

It will be apparent from the immediately preceding discussion that a variable voltage source, i.e., a source of voltage whose output level may be controllably varied, may be used in place of noise source 25, if it is desired to set or control the time delay in predetermined fashion. In such a case the time delay need not remain fixed but can vary from a minimum to a maximum value, and vice versa, in a progressive manner, or may undergo discrete variations in a selected sequence, according to the type of control exercised. Random variation of delay, however, is particularly advantageous in certain situations, as will be explained presently in conjunction with the exemplary problem of faithfully imitating the sounds of a conventional pipe organ, complete to random phasing and rushing air noise, with an electronic organ.

It will be understood also that a source of random voltage fluctuations will vary between practical voltage limits according to the type of noise source used. Moreover, the fluctuations need not be random in the absolute sense, but may be obtained from a conventional pseudo-random sequence (convertible to voltage) generator. The voltage range of the variable voltage source and the values of the circuit elements establishing the time constant for response of the switching elements of the multivibrator are selected to assure a time delay no greater than the time between successive trigger pulses. This, in turn, assures synchronization of the output pulses (start) with the trigger pulses.

Using the component values and types designated in FIGURE 1 and for an input square wave of ten volts peak-to-peak having a pulse repetition frequency of 1 kc./s., it was found that the duration of the quasi-stable state, i.e., from triggering to termination of the quasi-stable state, ranged virtually over the complete cycle without loss of synchronization. That is, reset occurred for the multivibrator prior to the start of each new trigger pulse at the input terminal, and varied practically from the beginning of one sync pulse to the beginning of the next, as shown by the output waveform at terminal 30.

Referring now to FIGURE 2, there is shown a divider chain, which may be used for tone generation in an electric organ, comprising a basic tone generator or master oscillator 40 which may, for example, simply be an astable multivibrator square wave generator, followed by successive noise-controlled delay multivibrator of the type described above and frequency divider (divide-by-two circuit) such as 46, 45-1, 47, 45-2, and so forth, depend-

ing upon the number of frequency divisions desired. Each frequency divider may be of any conventional type, such as a flip-flop, although it is to be understood that the invention is not to be limited to division by two, nor to square wave generation.

An output may be taken from master oscillator 40 and from each of the dividers to provide octavely related tones, each output also being provided to the next component in the chain, e.g., from master oscillator 40 to noise-controlled delay multivibrator 46.

FIGURE 3 illustrates the timing of the waveforms obtained at the output terminals of each of the components of the divider chain of FIGURE 2. For the sake of simplicity and clarity the wave shapes illustrated in FIGURE 3 have been idealized to zero rise and fall times and no overshoot or undershoot.

The output of tone generator 40 is a series of square waves 50 (FIGURE 3a) repeating, for example, at a frequency of 1760 c.p.s. Noise-controlled delay multivibrator 46 is set, that is, switched from a stable to its quasi-stable state, each time a positive-going wave is applied thereto, and resets over a randomly variable time interval having illustrative limits indicated by the cross-hatched area at the end of each pulse of the waveform 51 (FIGURE 3b), the output of multivibrator 46. The random time interval is determined by the amount of noise voltage present and reset may be arranged to occur sometime after a specified portion of a period of the input wave 50.

It will be apparent from the preceding description of the noise-controlled delay multivibrator that the actual time durations of successive pulses of waveform 51 will differ, their differences in width being equivalent to a frequency perturbation. It will also be apparent that the average frequency of the output waveform of delay multivibrator 46 or any of the succeeding components is unaltered. Referring to waveform 51, for example, it may occur that the first output pulse from delay multivibrator 46 terminates at a time indicated by the start of the cross-hatched area, whereas the second pulse terminates at a time indicated by the end of the cross-hatched area. The third pulse may terminate at a point in time within the cross-hatched area, and so on in random manner. The average frequency is unaffected because an output pulse is generated each and every time a positive-going input pulse 50 is applied to the multivibrator.

Each divided-by-two circuit 45-1 through 45-n changes state upon application of a negative-going voltage step thereto. In each case the delay perturbation of the preceding noise-controlled delay multivibrator is transferred to the flip-flop that it controls. For example, the delay perturbations of multivibrator 46 are transferred to flip-flop 45-1. The result is the output waveform 52 of divider 45-1, shown in FIGURE 3(c). Here, the pulse is characterized by a randomness of starting time as well as of termination time. Again, while the width of individual pulses will vary, the average frequency remains fixed. The positive-going portion of each pulse generated by divider 45-1 is utilized to trigger the next delay multivibrator 47 to its quasi-stable state, and so forth.

Since the time constants of successive delay multivibrator circuits in the chain increase by a factor equal to the division or multiplication factor introduced by the chain, the uncertainty in the delay variation of each of the delay multivibrators increases by that same factor, provided that the same amount of noise voltage is used in each. This is, of course, quite different from the situation in which the width of a pulse differs from the width of another pulse by a specified factor, a situation which would fail to provide the desired random phases of the octavely related tones generated by the divider chain.

Referring now to FIGURE 4, there is shown a transistorized circuit corresponding to the monostable multivibrator 46 and divider 45-1 portion of FIGURE 2. In this case the noise-controlled delay multivibrator is a

collector-coupled one shot circuit, analogous to a plate-coupled tube type monostable multi. In the stable state transistor 72 is on and transistor 70 is off. Pulses applied to input terminal 60 from the master oscillator (not shown) are differentiated and the negative-going trigger resulting from each differentiation is passed by diode 75 for application to the collector of transistor 70 and the base of transistor 72. If base drive is desired a positive trigger is instead applied to the base electrode of transistor 70. In either event, the multivibrator then undergoes a transition to the quasi-stable state, in which transistor 70 goes on and transistor 72 goes off, and remains in that state until transistor 72 comes out of cutoff. This occurs when the base voltage of transistor 72 overcomes the cutoff bias, over a period of time determined by the charging of capacitor 77 through resistor 78, and by the random fluctuations of noise source 80.

The random duration negative-going output pulses of the monostable multivibrator are applied to conventional bistable multivibrator 85 via coupling capacitor 87 and diodes 88 and 89. Since flip-flop 85 is conventional it need not be further described or discussed. It is sufficient to note that the output of this divider (flip-flop 85) is a randomly phased pulse train at half the average frequency of the output of the master oscillator.

The noise source for the delay multivibrator need not be located as shown in FIGURE 1 for a tube circuit nor as shown in FIGURE 4 for a transistor circuit, but may be placed in any convenient location in the circuit such that it will have the desired effect on the control electrode bias voltage for the second element (e.g., tube or transistor) of the multivibrator. For example, in FIGURE 4, noise generator 80 may instead be connected to the emitter of transistor 72 and, via a resistance, to the base of that transistor.

The component values and types designated in FIGURES 1 and 4 are for the sake of illustration and clarity only, being those used in construction embodiments of the invention but certainly subject to variation or complete change according to established techniques of circuit design in conjunction with the teachings presented herein.

The divider or multiplier arrangements of FIGURES 2 and 4 fall within the terminology "multiplier chains" since division is in fact multiplication by an inverse number.

Accordingly, while I have disclosed certain preferred embodiments of my invention, it will be apparent to those skilled in the art to which the invention pertains, that variations in the particular details of construction which have been illustrated and described may be resorted to without departing from the spirit or scope of the invention, as defined in the appended claims.

What is claimed is:

1. A tone generator for an electric organ, comprising:
 - a stable oscillator providing square wave outputs,
 - a noise controlled delay multivibrator coupled in cascade with said stable oscillator and arranged to have rises synchronized with said square wave outputs and falls which are random about an average value in response to said noise,
 - a first divide-by-two flip-flop synchronized in response to said falls,
 - a further noise controlled delay multivibrator coupled in cascade with said divide-by-two flip-flop and synchronized thereby to have average rises at half the frequency of said stable oscillator and falls which are random in response to said noise, and
 - a second divide-by-two flip-flop synchronized in response to the falls of said further noise controlled delay multivibrator.
2. The combination according to claim 1, wherein said noise controlled delay multivibrators each include a pair of transistors interconnected in a monostable configuration, and wherein each of said configurations includes a first transistor responsive to a synchronizing signal and

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having a collector and a second transistor coupled to said first transistor via a timing capacitor and having a base, said timing capacitor being connected from said collector to said base,

a source of steady DC supply voltage,
a timing resistance, and

a random voltage noise source connected in series with said source of steady DC supply voltage and said timing resistance to said base, to provide a trigger voltage at said base which has a random component.

3. A tone generator for an electronic organ, comprising a frequency divider chain having cascaded flip-flop divider elements,

a separate random delay device coupled between each pair of said divider elements, said delay devices each providing delays smaller than the period of the divider element during that delay device.

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4. The combination according to claim 3, wherein each of said delay devices includes a random noise controlled delay multivibrator having delays randomly varying about a constant average delay value.

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