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RANDOMLY-PERTURBED, LOCKED-WAVE GENERATOR

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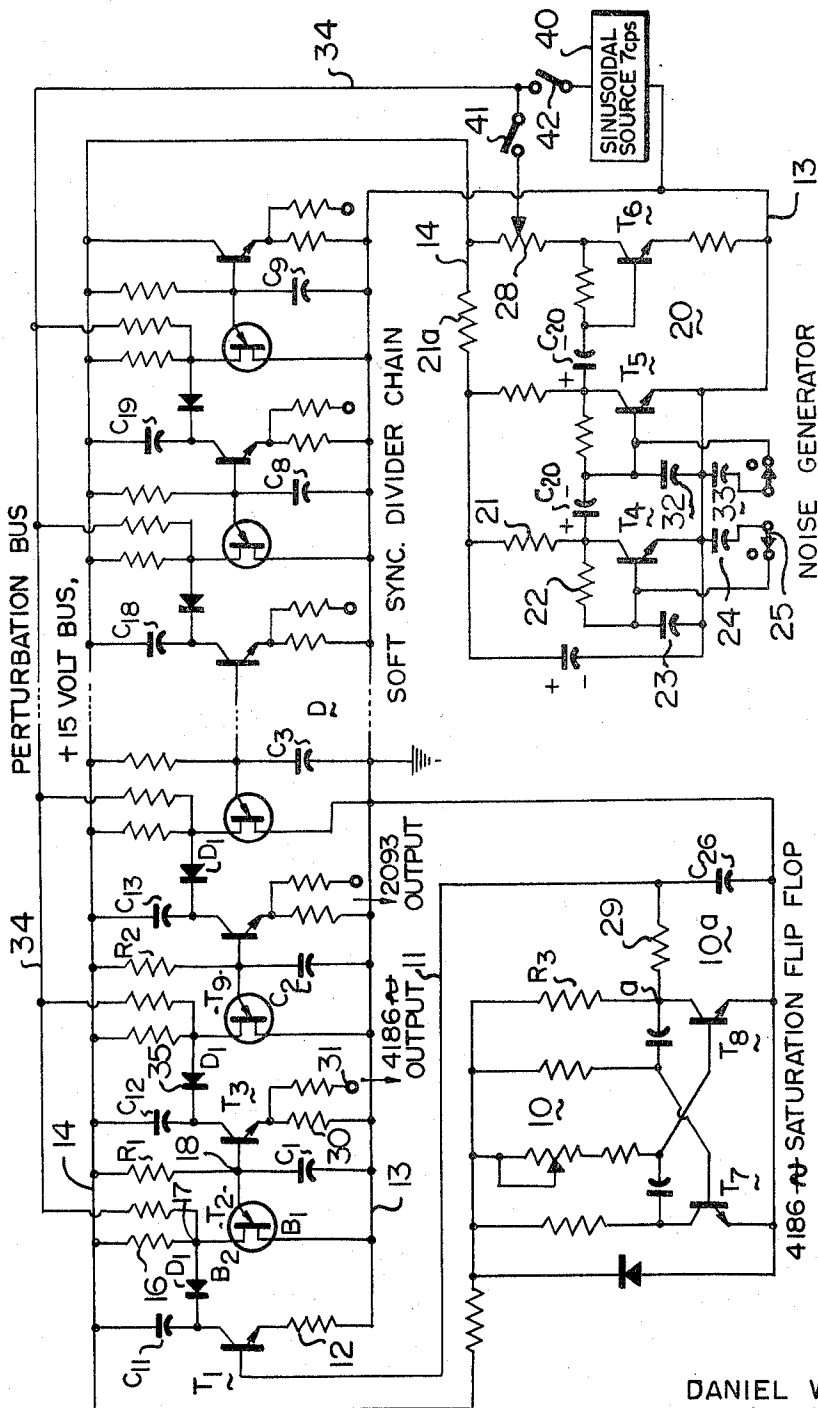


Fig. 1

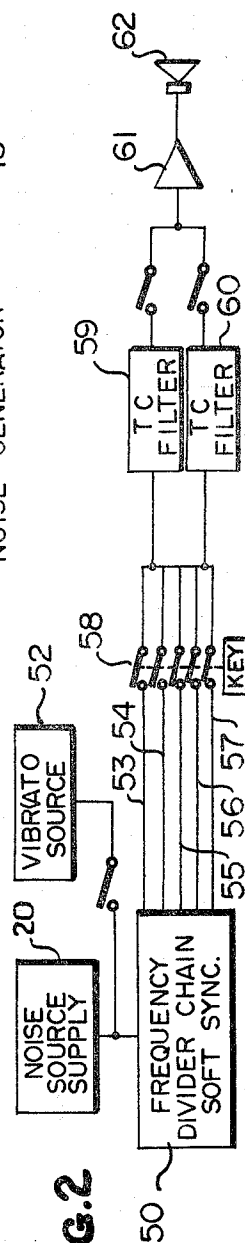


Fig. 2

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ABSTRACT OF THE DISCLOSURE

A tone generator for an electronic organ, employing frequency divider chains for generating octavely related tones, in which each stage of a divider chain is perturbed independently of the others on a per cycle basis while maintaining an average locked synchronism among the frequency divider stages of the divider chain.

The present invention relates generally to electronic organ tone generators, and more particularly to chains of frequency dividers which have provision for perturbing the dividers in uncorrelated fashion inter se.

It is known that organ pipe tone is inherently less stable than typical electronic organ tone generators and particularly that organ pipe tone is inherently less stable than electronic organ tone which derives from frequency divider chains. It is considered desirable to generate electronic organ tones which simulate as closely as possible the tones of organ pipes. Various attempts have made to introduce randomness into electronic organ tones. In one such attempt, random frequency modulation was induced in the master oscillator of a chain of frequency dividers used to generate organ tones. It was found that the succeeding stages of the frequency divider were less perturbed than the higher frequency stages and for an acceptable degree of randomness of the highest tones of the organ no randomness was audible in the lowest tones. Therefore, consideration was given to the possibility of perturbing the individual stages of a frequency divider in each octavely related chain of a generator. However, good stable divider circuits are inherently incapable of perturbation in the required degree. Randomness has been introduced into electronic organ tones, where the tone oscillators are independent of each other, but the use of independent tone oscillators implies losing the tuning advantage of locked octaves, which can be obtained from frequency divider chains. What is required therefore, is a chain of frequency dividers, each of the stages of which retains its average frequency quite precisely, but in which a random uncorrelated perturbation of the frequency of each stage relative to every other stage is attained. Thereby one would gain naturalness in individual tones, chorus effects from octavely related tones within a stop, and ensemble of octavely related stops derived from the same generator, all without losing the advantages of each of tuning and long term stability of the mean frequencies, which are inherent in use of frequency divider chains as organ tone generators.

The solution to the problem of providing a frequency divider chain in which the stages are perturbed in uncorrelated fashion is to trigger the successive stages of the frequency divider along the gradually rising portions of the sawteeth rather than in response to the rapidly sloping portions thereof, as is typically done in hard synch sawtooth divider circuits. Slope of the sawtooth wave is not really infinite in the vertical part of the sawtooth wave; but it is so steep typically that perturbation is ineffective along the time or phase axis. By triggering

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on the gradually rising portion of the sawtooth it is possible to obtain more phase modulation than is needed for organ tone purposes. In such a system a single noise source can be used on all perturbation inputs, and the desirably uncorrelated modulation among the several stages can be obtained because the trigger firing of the separate stages is occurring at different times, when the random voltage is different. Uncorrelated randomness can be obtained by using a noisy power supply for the frequency divider chain as a whole. However, in the approach of the present invention the amount of randomness can be adjusted for each divider and the separate dividers can be completely uncorrelated, by adding noise signal through separate resistances to the several stages, the power supply itself being conventional.

The random modulation of the several stages of the divider chain can be accomplished without the loss of the very important advantage, from the standpoint of tuning an electronic organ, of having locked octaves in a frequency divided chain.

In other words, the octaves will never be out of tune with each other on an average basis, but as long as the perturbing signals are applied, the octaves will seldom for long be precisely in tune with each other. The further advantage is obtained that if, for example, one wishes to have a bland tonal effect produced, or a tonal variety or expression which involves no randomness, it can be obtained instantaneously by simply switching off the random modulation. For example, if in an organ system a generator is to serve multiple duty, there can be switches which turn off the perturbation, or turn on a barely perceptible amount, or increase it to an optimum amount, or even to introduce an unnatural amount for special effects in highly descriptive music.

It is feasible, according to the invention, to frequency (vibrato) modulate all the stages of a frequency divider chain, rather than to randomly modulate, or to combine the two effects. Further, random modulation can be achieved by utilizing either a conventional DC power supply supplemented by noise, or by utilizing a noise supply as the only power source.

It is accordingly an object of the invention to provide a frequency divider chain in which the mean frequencies of the dividers are locked, but in which random perturbations are introduced independently into the separate dividers of the chain.

It is another object of the invention to provide a frequency divider chain in which random perturbations can be applied to each divider stage, with independent control of the extent of perturbation available for each one of the divider stages.

It is still a further object of the invention to introduce perturbations into sawtooth generators.

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 a preferred embodiment thereof, especially when taken in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a schematic circuit diagram of a preferred embodiment of the invention; and

FIGURE 2 is a block diagram of a modification of the system of FIGURE 1.

Referring now to FIGURE 1 of the drawings, 10 is a saturation flip-flop, of conventional character per se, which acts as the master oscillator or synch source of the present system. An output of flip-flop 10 is integrated in integrator 10a and then applied via lead 11 to the base of an NPN transistor T1, having its emitter connected through a small resistance 12 to a ground lead 13. The collector of T1 is coupled by a capacitor C11 to a +15 v.

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bus 14. Connected between bus 14 and ground bus 13 is a resistance 16 and a unijunction transistor T2. The junction 17 of resistance 16 and transistor T2 is connected by diode D1 to the collector of T1, diode cathode to collector. A timing circuit consisting of resistance R1 and capacitor C1 in series is connected between leads 14 and 13, and the junction 18 of R1 and C1 is coupled to the control electrode or emitter of the unijunction transistor T2 and to the base of an emitter follower NPN transistor T3.

The circuit 20 is an exemplary noise generator, including an NPN transistor T4, having a grounded emitter, a collector connected via resistances 21 and 21a to supply voltage bus 14, and a bias connection including a resistance 22 connected from collector to base. Capacitors 23, 24 and 32, 33 control the spectrum of the noise signal. Switch 25 is used to vary the modulation spectrum. The transistor T4 is selected to be noisy.

The noise signal provided by T4 is coupled to NPN transistor T5, having circuitry duplicating that of T4, and which, although a noise generator in itself, acts principally to amplify the noise output of T4. Transistor T6 amplifies the signal at the collector of T5, and is provided with a collector load in the form of resistance divider 28. Coupling between T4 and T5 as well as between T5 and T6 consists of a large capacitor C20, which acts as a high-pass filter and a DC-blocking capacitor. From divider 28 a desired level of noise signal (riding on DC) is provided to a perturbation bus 34, which distributes the noise signal to the several stages of the divider chain, generally indicated at D, and which may have as many stages as required by a given electronic organ, for which it constitutes a tone generator.

The saturation flip flop 10 provides a square wave voltage at point a which varies between zero and the voltage set by the reference diode. The integrating action of resistor 29 and capacitor C26 converts the square wave to a semi-triangular wave. The voltage applied to the base of T1 is therefore approximately triangular.

The construction of the unijunction transistor is well known. Two ohmic contacts B1 and B2 are made at opposite ends of a small bar of n-type silicon semiconductor. A single rectifying contact, called the emitter E, is made on the opposite side of the bar close to B2. An interface resistance then exists between B1 and B2. B1 is grounded and a positive voltage applied to B2. With no emitter current flowing, the silicon bar acts as a voltage divider with respect to the emitter, a certain fraction V_e of the positive voltage appearing at the emitter. If the externally applied emitter voltage is less than V_e the emitter will be reverse biased, but if the externally applied voltage is greater than V_e the emitter will be forward biased and current will flow. The emitter to B1 circuit of the transistor has a negative resistance characteristic, so that a rapid increase of current occurs.

The circuit containing transistors T1, T2, and T3 converts the semi-triangular wave, at the base input of T1, to a sawtooth wave at the emitter output of T3 without changing the average frequency, although the instantaneous frequency can be changed by the perturbation voltage.

During each of the positively going portions of the semi-triangular wave applied to the base of T1, the conductivity of T1 increases. The collector current for this transistor is supplied from the +15 v. bus, through resistor 16 and diode D1, producing a moderate drop in the potential of point 17. At the same time the voltage at point 18 rises as capacitor C1 is charged through resistor R1 from the +15 v. bus. The falling voltage of point 17, modulated randomly by the perturbation voltage, and the rising voltage of point 18 will at some point establish the breakdown requirements for the unijunction transistor T2, and the capacitor C1 will discharge rapidly through the emitter circuit of T2 thus producing a sawtooth wave at the base of transistor T3. During the breakdown of T2 its B2 voltage drops to a very low value. This drop in voltage is isolated from the collector of T1 by diode D1 which is now reverse biased. During the short time that T2 is in

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the breakdown condition, the collector voltage of T1 is sustained by capacitor C11, so that sawtooth signals cannot be propagated backward through the divider chain.

The sawtooth appearing at the base of T3 is transferred by emitter follows action to the emitter of T3 with no phase inversion and by amplifier action, with gain less than one, to the collector of T3, with 180° phase inversion. The sawtooth wave at the emitter of T3 is transferred to the output terminal through the decoupling resistor 31. The inverted sawtooth at the collector of T3, combined with the perturbation voltage, serves as the synchronizing signal for the following unijunction transistor T9. In this and all following stages the time constants have been set so that the unijunction transistor breaks down on every second sawtooth appearing at its base 2 terminal, thus producing a frequency division of two at each successive output.

The noise signal on perturbation bus 34 is applied to the base B2 of the unijunction transistors T2, T9, etc., correspondingly in all stages of the divider chain.

The sawtooth frequency divider of the present invention is of a type known as "soft synch," to be distinguished from "hard synch," which has previously been exclusively employed in tone generators for electronic organs. The hard synch divider employs the vertical slopes of wave forms generated by preceding stages to trigger succeeding stages. The soft synch chains utilize the attainment of a voltage level along the slow rise time slopes of wave forms generated by preceding stages to trigger succeeding stages.

It is only soft synch stages which can be readily perturbed to the extent required to randomize tones, yet the perturbations do not imply that the chain is not locked, on an average basis. Therefore, changing the frequency of the highest frequency of the chain, correspondingly changes the average frequencies of all dividers of the chain. But the per cycle frequency of each divider is perturbed about its average frequency, and the perturbations are independent of one another in the several stages. Further, each stage can readily be subjected to different degrees of perturbation, without affecting perturbations of other stages except as a second order effect. The term perturbations should not be taken to exclude sinusoidal or complex periodic voltages, so that the present invention can be used to produce vibrato, with a single vibrato oscillator, say at 7 c.p.s. phase modulating each of the stages of a divider chain to a different degree. In this respect an interesting effect can be achieved by combining vibrato signal and noise signal, as the perturbation.

While a single preferred modification of the invention has been disclosed, as exemplary, a wide variety of divider stages has been and may be devised, utilizing various voltage sensitive devices such as four-layer diodes, thyatrons, neon bulbs, and the like to replace unijunction transistors. The essential feature of all such systems remains, however, the use of soft synch dividers, in which perturbations or control signals are employed to vary synch time from stage to stage. The precise character of the noise source, or whether in fact noise is employed as the perturbing signal, is not material.

In lieu of the noise source 20, a vibrato source 40 may be connected to perturbation bus 30, or both noise and vibrato may be so connected, by manipulation of switches 41, 42.

Conventional frequency dividers employed in organ tone generators have division ratios of two per stage. The divider of the present invention can provide any reasonable integral division ratio, i.e. 2, 3, 4, 5, etc., and such division ratios are finding utility in electronic organs.

In the system of FIGURE 1, a steady DC voltage bus is provided, and also a perturbation bus. It is feasible however, so long as a soft synch divider chain is employed, to utilize a noise source, or noise plus DC, as a sole voltage supply for the chain, and to accomplish the results of the invention, i.e., to have locked synchronism on average for the chain but to perturb all stages of the chain in uncorrelated fashion, on a short term basis.

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Referring to FIGURE 2, the frequency divider chain 50 may be, in detail, the system of FIGURE 1, except in that the noise source 20 may be alone utilized as a voltage supply for the chain. A vibrato source 52 may superpose its output on the noise supply 20. The stages of divider chain 50 may provide output, as at 53, 54, 55, 56, 57, to key switches 58, and the latter may supply tones, when actuated, to tone color filters 59, 60, for amplification by amplifier 61 and radiation by loudspeaker 62.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In an electronic organ:
a tone generator comprising a frequency divider chain, said frequency divider chain including frequency dividers connected in cascade, each of said frequency dividers being arranged to generate sawtooth waveforms, each of said sawtooth waveforms having a slowly varying portion joined with a rapid return portion, means including a source of perturbing signal applied separately and independently in parallel to said frequency dividers, said last means being responsive only to a slowly varying portion of the waveform produced by a preceding one of said frequency dividers for initiating the return portion of a succeeding frequency divider connected in cascade with said preceding one of said frequency dividers.
2. The combination according to claim 1 wherein said last means is a means for separately and differently perturbing a plurality of said slowly varying portions.
3. The combination according to claim 2 wherein said means for perturbing includes a noise signal source.
4. The combination according to claim 2, wherein said means for perturbing includes a vibrato source.
5. The combination according to claim 2 wherein said means for perturbing includes a single noise generator, and means for applying the output of said noise generator concurrently to all said frequency dividers.
6. In combination:
a source of periodic sawtooth waveform having a slow rise and a rapid return,
a soft synchronized sawtooth oscillator having a period approximately integrally related to the period of said sawtooth waveform,
said soft synchronized sawtooth oscillator providing a wave having a slow rise and a rapid return,
means perturbing the slow rise of said periodic sawtooth waveform, said sawtooth oscillator including means responsive only to a predetermined level of said periodic sawtooth waveform for effecting a transition from its slow rise to its rapid return.
7. In an electric organ:
a tone generator
said tone generator comprising a cascaded sequence of soft synchronized frequency dividers,
means for individually and differently perturbing the frequencies of each of said frequency dividers each independently of the others on a per cycle basis while maintaining an average locked synchronism among said frequency dividers, and
means for deriving a tone signal from each of said frequency dividers.
8. The combination according to claim 7 wherein said means for individually perturbing comprises a single noise source connected to said frequency dividers.
9. The combination according to claim 7 wherein said means for individually perturbing comprises a single

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vibrato signal source connected to said frequency dividers.

10. The combination according to claim 7 wherein said means for individually perturbing includes both a single noise source and a vibrato signal source, and means for selectively connecting one or both of said noise source and vibrato signal to said frequency dividers.

11. In a tone generator for electronic organs:

a frequency divider chain of the soft synchronized type,
a noise source voltage supply connected to said frequency divider chain,
key switches for calling forth individual tones from the stages of said frequency divider chain,
tone color filters connected in cascade with said key switches, and
a loudspeaker connected in cascade with said tone color filters.

12. The combination according to claim 11, wherein said frequency divider chain includes plural dividers connected in cascade:

each of said dividers including a two state device having two primary electrodes and a control electrode, means for deriving a sawtooth voltage from each preceding stage and applying said sawtooth voltage to the primary electrodes of the two state device of the next succeeding stage,

RC circuits connected between the control electrodes and a primary electrode of each of said two state devices for generating sawtooth voltages at said control electrodes,

said two state devices being arranged to fire on attainment of a predetermined amplitude relation between the voltage across said primary electrodes and between said primary electrode and said control electrode, and

means for perturbing said amplitude relation.

13. The combination according to claim 12, wherein said two state devices are unijunction transistors.

14. The combination according to claim 12, wherein said two state devices are solid state switching devices.

15. In an electric organ:

a tone generator comprising a frequency divider chain, including frequency dividers connected in cascade, each of said dividers including a triggering device having two states and including two primary electrodes and a control electrode,

means for generating a sawtooth voltage across said primary electrodes and another sawtooth voltage between said control electrode and one of said primary electrodes, said triggering device being arranged to fire in response to attainment of a predetermined amplitude relation between the slow rises of said sawtooth voltages to the exclusion of the rapid falls, and

means for perturbing the amplitude relation of said sawtooth voltages continuously.

16. The combination according to claim 15 wherein said triggering device is a unijunction transistor.

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