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ELECTRONIC MUSICAL INSTRUMENT PLURAL TONE GENERATOR SYSTEM WITH CHORUS EFFECTS

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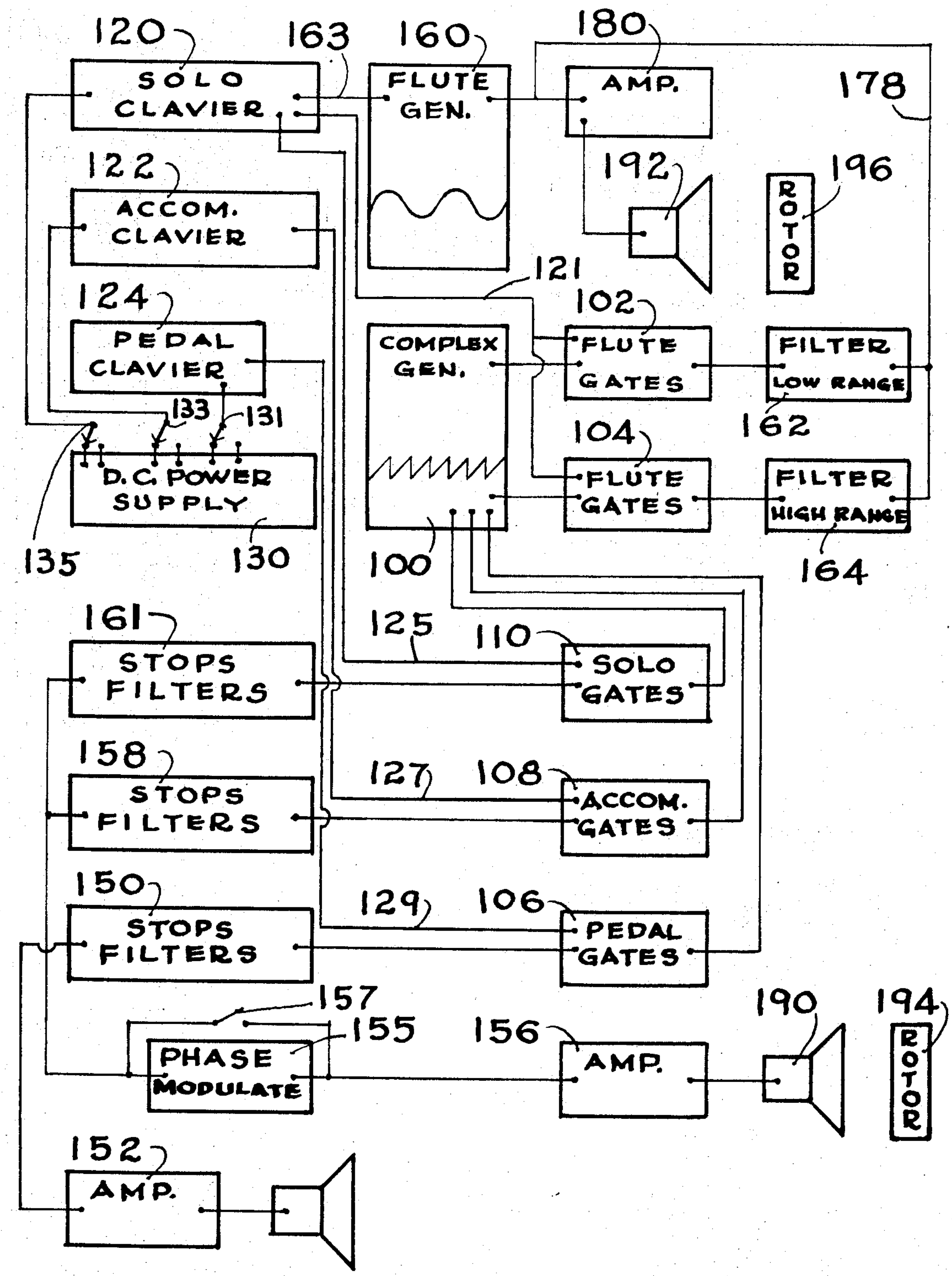

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ELECTRONIC MUSICAL INSTRUMENT PLURAL TONE GENERATOR SYSTEM WITH CHORUS EFFECTS

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ABSTRACT OF THE DISCLOSURE

A first, full-range tone generator operates in parallel with a second, short-range generator which includes only those frequencies at which the sensitivity of the human ear to ensemble or chorus effects is substantial. A first amplifying and transducing channel is associated with signals from the short-range generator and from those portions of the full-range generator above and below the short-range generator frequencies. A second amplifying and transducing channel is associated with signals from the full range generator only. A pair of sound transducers may be rotated at the same or different speeds.

This invention relates generally to electronic musical instruments and particularly to an improved system of oscillation generators for such instruments.

Most electronic organs now manufactured use tone frequency oscillation generators of the cascaded frequency divider type. One such tone generator uses cascaded blocking oscillation as described in my Pat. No. 3,143,712 issued Aug. 4, 1964.

Another widely used frequency divider is the bi-stable multivibrator or flip-flop. This circuit is currently popular because it is easily manufactured and uses low cost semiconductors. Frequency divider type generators have the advantage of being inexpensive to construct because only the master or controlling oscillators (usually twelve in number) require tuning. Thus it is easy to design a complete system possessing great stability. The "flip-flop" generator also has the advantage that all of the frequency divider stages can be identical as to circuit values, and can be fabricated by various "integrated circuit" techniques.

On the other hand, frequency divider tone generators necessarily produce tone signals having fixed phase relationships between all of the notes controlled by a given master oscillator. Usually this means that all of the octaves of a given note are phase locked. Also it is usual to use only one tone generator for a complete organ and this means that whenever notes of a given nomenclature (C–C–D, etc.) are sounded from any key on the instrument, all such notes will be dead in tune with one another, and the sounding of such plural notes produces the effect of only a single note having a somewhat peculiar harmonic series. Totally lacking is the beating effect that is one of the most important elements of "chorus" or "ensemble."

For this reason the more expensive electronic organs usually forego the obvious simplicity of frequency dividers and use independently tuneable oscillators for each note in each octave. In addition many larger organs use several complete sets of oscillators, such as a set for each manual, or a set for each of several different tone qualities. Such instruments are generally acknowledged to be superior from an esthetic point of view but are necessarily expensive and more difficult to keep in adjustment.

A major object of this invention therefore, is to provide a simplified generator system capable of producing effects ordinarily associated with much more complex equipment.

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Another object of the invention is to provide a generating system providing enhanced chorus effects with a minimum number of tuneable oscillators.

Another object of the invention is to provide a generating system having an unusally high degree of frequency stability.

Still another object of the invention is to provide a D.C. activated tone generation system, wherein musical balance between the various divisions, or pitch levels, of an organ can be achieved by activating the tone sources with different keying voltages from the various keyboards of the instrument.

Other objects and advantages will become apparent from the more detailed description which follows.

In the accompanying drawing:

The sole figure is a block diagram of an organ embodying one form of the invention.

Referring to the figure, **100** is a frequency divider type tone generator producing complex waveforms and may be according to my aforementioned U.S. patent. In the exemplary organ described, this generator has a range of 8 complete octaves from C zero (32.7 cycles second) through C eight (8372 cycles/second). Associated with this tone generator are several sets of signal gating circuits **102**, **104**, **106**, and **110**. These gate circuits may be diode gate circuits as shown in my U.S. Pat. 3,178,-499 dated Apr. 13, 1965, or they may be any of the diode, transistor, vacuum tube, photo electric, or other gating circuits that are known to those skilled in the art. Their purpose is to transmit signals from the frequency divider tone generator to appropriate audio channels in response to the operation of the keyboards **120**, **122**, and **124**. The pedal gates **106** for example, are associated with the pedal keyboard and pedal keyswitches **124** so that when pedal keys are depressed, the associated pedal keyswitches complete circuits between the power supply **130** and the appropriate pedal gate, which causes tone signals to be applied through the conventional pedal stop switches and filter circuits **150**, to the pedal amplifier **152**. Examples of suitable stop switch and filter circuits are shown in U.S. Pat. 2,233,948 issued in the name of Winston Kock, dated Mar. 4, 1941. Similarly, gates **108** and **110** are associated with solo and accompaniment keyboards **120** and **122**, and with stops and filters **158** and **161** and with amplifier **156**.

Thus far we have described a conventional electronic organ system having limited chorus effects, for the reasons described earlier. In addition to this main or complex system, I have provided an additional audio channel which in this example is adapted to handle signals having a predominantly flute-like character.

Notes from approximately E_2 (164.8 cycles/second) which is the note E below middle C, through B_4 (987 cycles/second) are derived from the independent tone generator **160**. Each note throughout this range is produced by an independently tuneable oscillator which for example may be according to my U.S. Pat. 2,924,784 dated Feb. 9, 1960. Above and below the range of oscillators specified, flute signals for the "flute organ" system are derived from the frequency divider generator **100**, and are gated through the flute gates **102** for notes below E_2 and through flute gates **104** for notes above B_4. Filters **162** and **164** are associated with gates **102** and **104** respectively. These wave filters may be of the low pass or bandpass type and are for the purpose of filtering the complex waves generated by the generator **100** to a wave form compatible with that produced by generator **160**. Such filters are well known in the art and may be R–C, L–C, or active filters employing amplifiers with frequency-selective feed back.

Obviously the notes might be filtered in small groups of 6 or 12 notes if desired, and filters **162** and **164** are intended to indicate any type of suitable filter. The output signals from generator **160** and from filters **162** and **164** are all applied to the flute amplifier **180** via conductor **178**. Thus, the complete flute generating system is a hybrid, using some oscillations generated by each of the generators **100** and **160**. The gates **102** and **104** and the generator **160** are of course operatively associated with one or more of the keyboards.

Thus, solo clavier **120** has a branched cable **121** extending to gates **102** and **104**, a cable **163** extending to generator **160**, and a cable **125** extending to solo gates **110**. Accompaniment clavier **122** has a cable **127** extending to gates **108**. Pedal clavier **124** has a cable **129** extending to gates **106**.

Means are provided for delivering different potentials to the claviers, to emphasize the notes played on any selected clavier by changing the relative amplitude of the signals generated. For instance, the D.C. power supply **130** has three selective switches for receiving either 10 volts or 20 volts from the supply **130**. Switch **131** delivers the selected potential to the pedal clavier **124**; switch **133** delivers to the accompaniment clavier **122**; and switch **135** delivers to the solo clavier **120**.

To avoid complicating the drawings, detailed wiring has not been shown, but it is to be understood that the wiring between the key switches and the various tone generators and gating circuits may well include the usual means for octave coupling, unification and the like. By this, it is meant that the depression of a single key on a keyboard might sound but a single note, or it might sound several octavely or other related pitches simultaneously.

Each of the amplifiers is connected to a loud speaker as indicated by the reference characters **190** and **192**, and either or both of the loud speakers may be associated with a rotor such as those indicated by reference characters **194** and **196**.

These rotors may be rotary sound channels as shown in United States Pat. Re. 23,323 to Donald J. Leslie, or other means for causing an effective rotation of the source of sound from the loud speaker about an axis. Any of the many known means for physically changing the location of one or more loud speakers may be considered a "rotor" in the sense that the term is herein used. The use of rotors for tremol purposes and for chorous effects is well known, but their use in connection with this invention is especially desirable for reasons that will presently become clear.

The particular arrangement of generators disclosed is exemplary only, and of course some modification can be made without departing from the spirit of the invention. The approximate arrangement is very important however in achieving the desired objectives as previously outlined, because it optimizes the desirable beating or chorus effects obtainable with a minimum of apparatus. It can be demonstrated by subjective tests that the maximum illusion of chorus (sometimes described by such subjective terms as bigness, depth, fluidity, etc.) is closely related to the beating that takes place between signals of the same nominal frequency from separate locations in space. It was also discovered that beating between signals in the low-middle audio region (say 1000 cycles per second) produces a strong illusion of chorus, while beating between signals above this range, produce little subjective "thrill" and tends to produce an unpleasant reaction in almost all listeners. Beating below about 100 cycles per second produces a strong illusion of motion, but where the beating frequencies are close enough to sound "in tune" the beat occurs so slowly that it may not be apparent except in very slow playing. Beat "rate" was discovered to be important, in that where beating occurs too slowly the chorus effect was at a minimum. At the opposite extreme, rapid beats above a few beats per second created an unpleasant out-of-tune or throbbing effect that did not appear to have any desirable esthetic attributes.

If we now examine the beating that takes place in an organ according to the invention, it will be seen that we obtain a large number of chorus-contributing, desirable beats and a minimum of undesirable beat effects.

The most important chorus beats are probably between unison pitches. Thus, when any note between E_2 and B_4 sounded, and where a flute voice and a main voice are played together, a beat will occur between the flute signal as projected from loud speaker **192**, and the fundamental component of the complex wave tone projected from loud speaker **190**. Notice that statistically, an extremely high percentage of notes called for in virtually any type of musical selection lie within this range. In addition, chords are almost never sounded below the note E_2, because they become unpleasantly "muddy." Above B_4, a desirable chorus effect is almost totally lacking and when generators of usual stability are employed, even very small percentage differences in nominal frequency result in fast, unpleasant beats. It is therefore an important advantage to derive both the flute and main voice signals from a common generator. To avoid the usual locked sound, the use of a rotor on either or both channels is advantageous. At frequencies having relatively short wave lengths, a rotor is a very effective phase scrambler. This is true whenever the effective source of the sound is shifted by a distance equal to at least a substantial part of a wave length. The formula relating wave length to frequency is

$$X=\frac{\text{speed of sound in air}}{\text{frequency}}=\frac{1090 \text{ ft./second}}{\text{frequency}}$$

Substituting figures in the formula shows that a frequency of 1090 cycles per second has a wave length of one foot. One foot is also the size of a typical rotor that is practical for incorporation in a musical instrument.

These relationships explain the reason for the switch back to a single generator system for notes above C_5 (1046 cycles per second). Subjective tests confirm the validity for this approach. A group of listeners was unable to discern any difference in chorus effect between the system of the invention and separate well tuned generators at frequencies above C_5.

Using rotors on both channels creates actual beats between the differently processed signals when the rotors are operated at slightly differing speeds.

So far we have considered beats between unison frequencies. Important chorus-producing beats also occur between the lower partials of the complex wave forms (which are usually strong) and notes from the other generator having nominal frequencies substantially coincident with the partials. Thus, for example, the second harmonic component of a complex wave emanating from loud speaker **190**, will produce a desirable beat with a flute tone an octave higher than the fundamental of the complex wave emanating from loud speaker **192**. When several pitches of flute tone are played together a complicated beating pattern occurs between the lower partials of the main generator notes, and the various flute tones, all of which are derived from independent generators throughout the "chorus" range.

An additional major advantage of this invention is that it becomes practical to incorporate into the instrument a high degree of control over the intensity levels of the different divisions of the organ by D.C. means. Referring again to the sole figure, if the accompaniment keying circuits are connected to a potential of, say, 10 volts, and the solo playing circuits were connected to a different potential such as 20 volts, the accompaniment voices will sound at a reduced level as compared with the solo voices. This can be very valuable musically, especially in connection with unified stops. Where individual oscillators are used however, it is difficult to operate the oscillators over a very wide range of operating voltages without affecting the tuning to an unacceptable degree. At low frequencies, however, a much higher percentage of frequency error is permissible than at high frequencies. This is because the frequency error is made apparent by the beating effects that take place when a plurality of notes are sounded together. Since even an extremely small frequency error at high frequencies results in undesirably rapid beats, almost no error is permissible. But at these critical frequencies, in an organ according to the invention, the notes are derived from gate circuits associated with the frequency divider tone generator, and no tuning problem exists.

Others may readily adapt the invention for use under various conditions of service by employing one or more of the novel features disclosed or equivalents thereof.

For instance, each of the generators **160** and **100** may have either independently tuned oscillators or locked frequency-divider oscillators; and each of them may deliver either signals containing natural harmonics or signals substantially devoid of harmonics; and all of the combinations thus included have many of the advantages of the invention. The preferred embodiment is with generator **160** consisting of independently tuned oscillators generating signals devoid of harmonics, and generator **100** having locked oscillators generating signals rich in harmonics. With either electronic or acoustic phase shifting, the preferred frequency of modulation is at a vibrato or a sub-vibrato rate. At **155** I have indicated electronic phase shifting means, such as that disclosed in U.S. Pat. 3,146,-292 to Donald L. Bonham, issued Aug. 25, 1964, and a by-pass switch **157** to be closed when the user prefers to use the rotor **194**.

As at present advised, with respect to the apparent scope of my invention, I desire to claim the following subject matter:

1. In an electronic musical instrument providing chorus effects, the combination comprising:

- a main tone generator for producing predetermined signal frequencies corresponding to notes of the musical scale,
- a second tone generator for producing predetermined signal frequencies corresponding to notes of the musical scale of a lesser frequency range than that of the main tone generator,
- a first amplifier and transducer means connected to receive signals from said main tone generator,
- a second amplifier and transducer means connected to receive signals from said second tone generator,
- and means connected between said main tone generator and the input of said second amplifier for feeding signals to said second amplifier outside the frequency range of said second tone generator.

2. The combination according to claim **1** in which said main generator is of the locked frequency divider type and produces signals rich in harmonics, and in which said second generator has independently tuned oscillators and produces signals substantially devoid of harmonics.

3. The combination according to claim **1** further including a vibrato rate phase varying means connected between one of said tone generators and the associated amplifier and transducer means.

4. The combination according to claim **3** wherein said vibrato rate phase varying means is electronic means operating on the phase of the signal.

5. The combination according to claim **1** further including acoustical vibrato rate varying means associated with at least one of said transducer means.

6. The combination according to claim **1** further including acoustical vibrato rate varying means associated with each of said transducer means.

7. The combination according to claim **6** wherein the rates of said vibrato rate varying means are different.

8. The combination according to claim **3** wherein an acoustical vibrato rate varying means is associated with said one transducer means.

9. The combination according to claim **1** wherein said means includes a first filter and a second filter, said first filter passing frequencies lower than, and said second filter passing frequencies higher than, the frequencies provided by said second tone generator.

10. In an electronic musical instrument providing chorus effects, the combination comprising:

- a main tone generator for producing predetermined signal frequencies corresponding to notes of the musical scale.
- a second tone generator for producing predetermined signal frequencies corresponding to notes of the musical scale of a lesser frequency range than that of the main tone generator,
- a first amplifier and transducer means connected to receive signals from said main tone generator,
- a second amplifier and transducer means connected to receive signals from said second tone generator,
- and means connected between said main tone generator and the input of said second amplifier for feeding at least substantially only those signals from said main generator not included in the range of said second tone generator to said second amplifier.

References Cited

UNITED STATES PATENTS

3,215,767	11/1965	Martin	84—1.22 X
3,229,019	1/1966	Peterson	84—1.01
3,026,757	3/1962	Ziehlke	84—1.24 X
2,310,429	2/1943	Hanert	84—1.25
3,007,361	11/1961	Wayne	84—1.01
3,069,958	12/1962	Arsem et al.	84—1.25
3,147,333	9/1964	Wayne	84—1.24
3,450,825	6/1969	Cunningham	84—1.24

WARREN E. RAY, Primary Examiner

U.S. Cl. X.R.

84—1.25

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,538,234 Dated November 3, 1970

Inventor(s) Richard H. Peterson

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 27, "of-" should read -- of --; line 53, "(C-C-D, etc.)" should read -- (C-C#-D, etc.) --. Column 2, line 22, "(32.7 cycles second)" should read -- (32.7 cycles second) --; line 25, "102, 104, 106 and 110" should read -- 102, 104, 106, 108, and 110 --. Column 3, line 23, "122;" should read -- 122 --; line 45, "tremol" should read -- tremolo --; same line 45, "chorous" should read -- chorus --. Column 6, line 27, the period should be a comma.

Signed and sealed this 13th day of April 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Paten