May 17, 1966 D. J. LESLIE 3,251,924

APPARATUS FOR PRODUCING A DERIVATIVE CELESTE OR CHORUS RANK FOR ELECTRONIC ORGANS

Filed Feb. 18, 1964 4 Sheets-Sheet 1

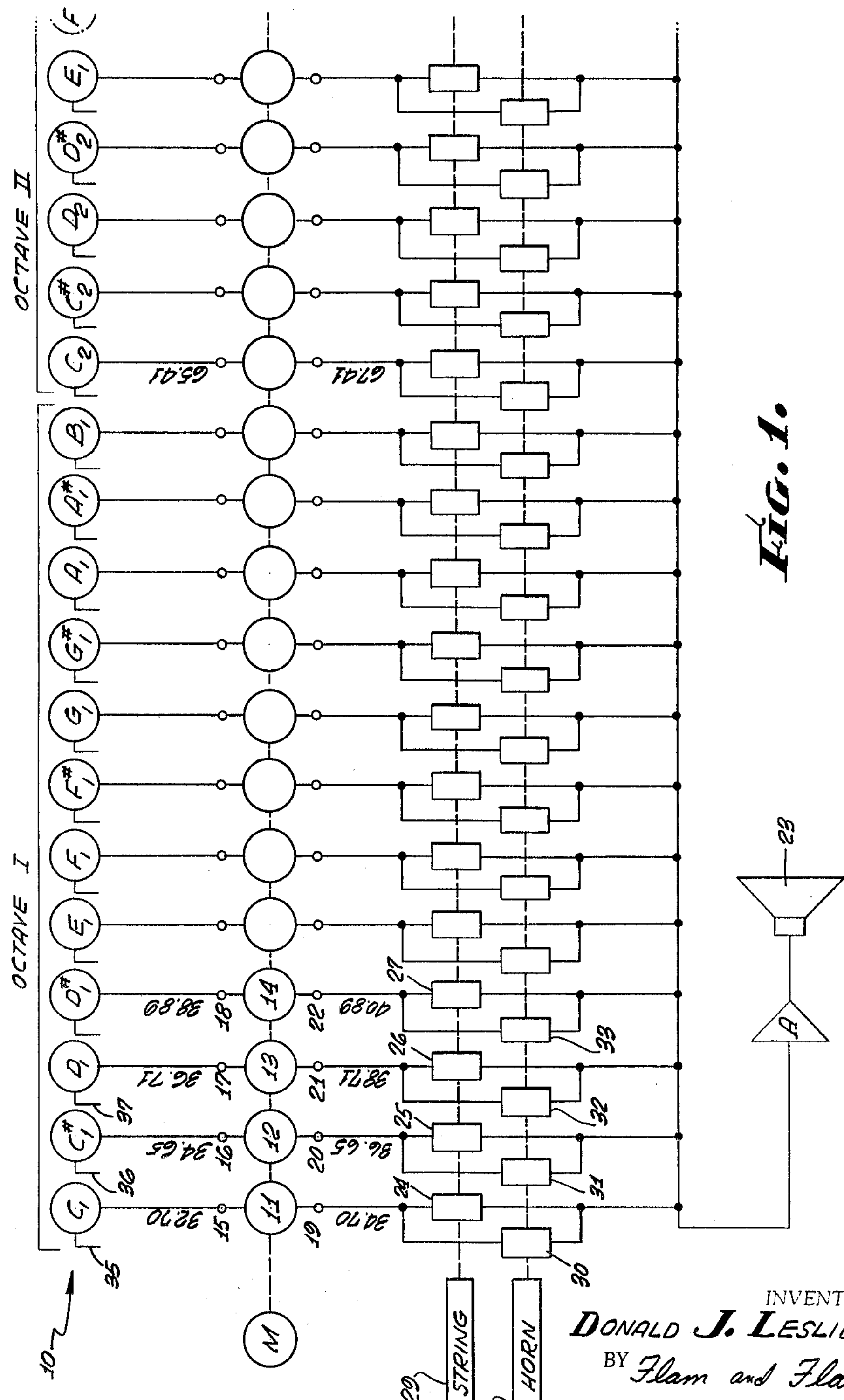

FIG. 1.

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Filed Feb. 18, 1964 4 Sheets-Sheet 2

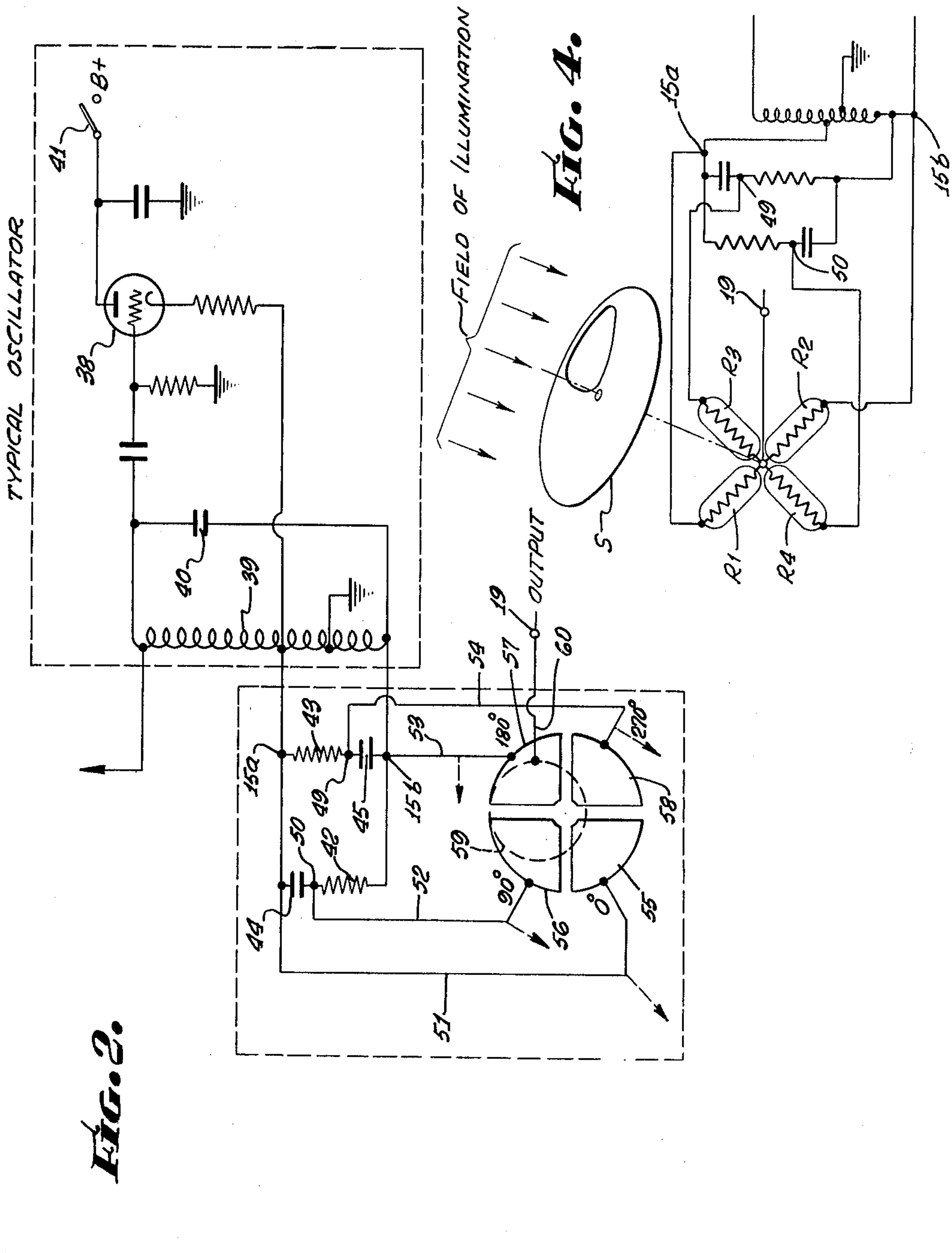

FIG. 4.

FIG. 2.

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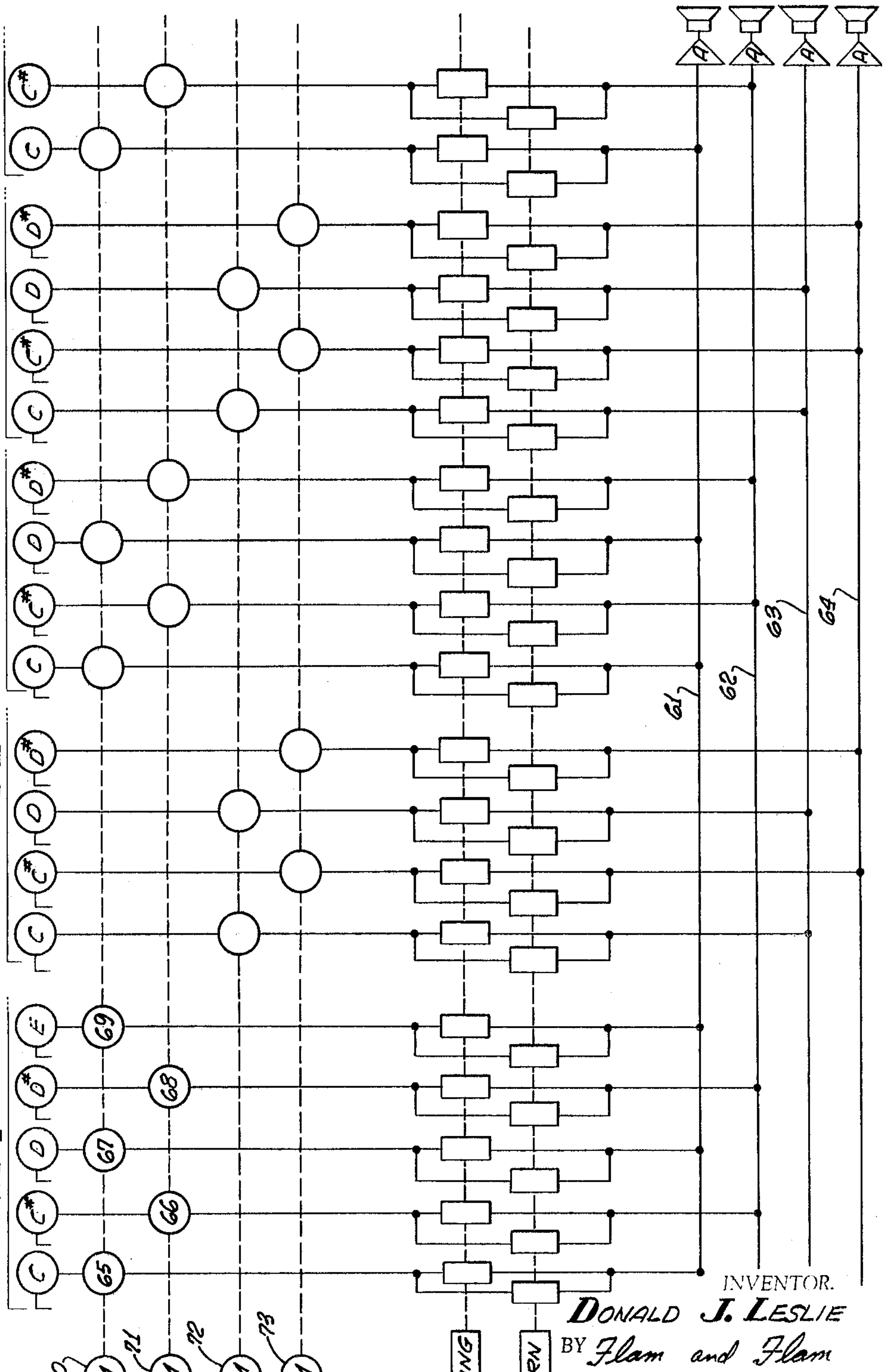

FIG. 3.

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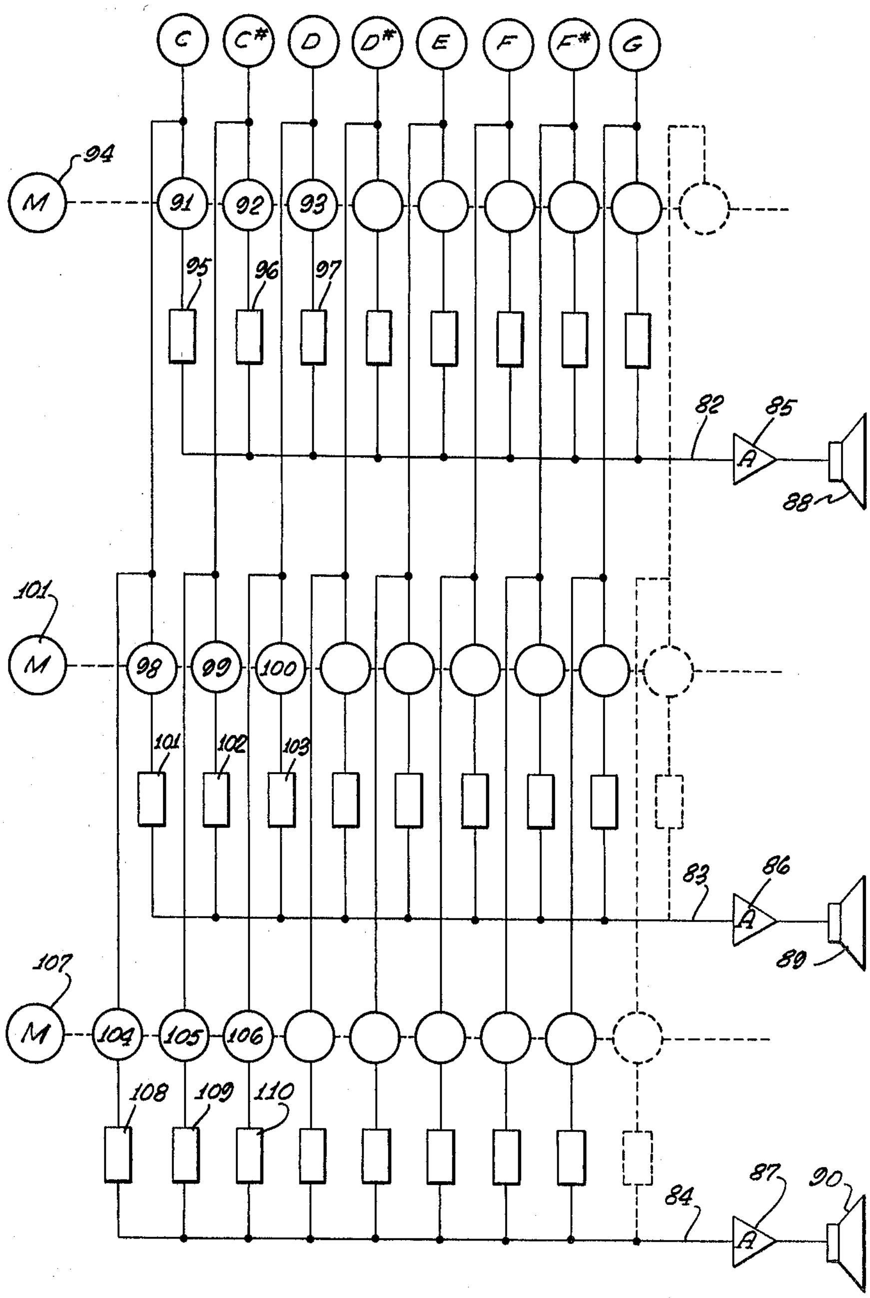
FIG. 5.



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3,251,924
APPARATUS FOR PRODUCING A DERIVATIVE CELESTE OR CHORUS RANK FOR ELECTRONIC ORGANS

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13 Claims. (Cl. 84—1.24)

This invention relates to electronic organs, and particularly to apparatus for producing chorus or celeste effects.

In the past, it has been common to provide a complete extra set of generators in order to obtain a chorus or celeste effect. A not inconsiderable objection to this arrangement is that keeping the organ in tune involves periodic adjustments of two sets of generators rather than one. It has been proposed to utilize frequency changing devices in conjunction with the main set of generators in order to derive the equivalent of a second set of generators with slightly different tuning. Such an arrangement has been proposed, for example, in United States Letters Patent No. 3,004,460 to William C. Wayne, Jr., issued October 17, 1961, and entitled, "Audio Modulation System." All impulses in a frequency band are lowered or raised by a certain amount, for example, two cycles per second. Instruments incorporating such systems have been marketed, but with limited acceptance since the resultant sounds do not truly conform to those of a celeste rank of pipe organs. One of the reasons for this is that the harmonics are raised the same number of cycles per second as the fundamentals, and thus the proportionate relationship of the harmonics is disturbed. Thus A_{440} becomes A_{442} and its second harmonic sounds at 882 cycles per second, which is two cycles per second short of a proper proportionate relationship. Some attempt to compensate for this defect has been made by providing a series of bands across the frequency spectrum, and providing greater frequency deviations in the upper ranges. Yet this solution is imperfect since the fundamentals of the higher frequencies will be shifted a great deal more than the fundamentals of the lower frequencies, whereas in a celeste rank of pipes, the pitch deviation is fairly uniform throughout.

The primary object of this invention is to provide a system for deriving the equivalent of a celeste rank by the aid of frequency changing devices maintaining a fairly uniform pitch deviation as well as a proportionate relationship of harmonics. In order to accomplish this result, I provide shift of the generator impulses at a stage where they are substantially sinusoidal in form, or relatively free of harmonics, and then subject the original and frequency altered sinusoidal impulses to apparatus for adding harmonics.

Another object of this invention is to provide apparatus of this character in which impulses corresponding to various notes are grouped and translated in saparate electrical channels whereby different notes have slightly different pitch deviations more closely to simulate pipe organ characteristics, and whereby beat effects due to interaction of impulses in fourth, fifth or octave relationship are minimized.

A pipe organ, which designers of electronic organs always seek to simulate, produces different voices by the use of different sets or ranks of pipes. These pipe voices retain their identity even though pipes for the same note are sounded in other ranks of pipes. One of the reasons for this is that the tuning of the D_3 pipe, for example, in one rank has a frequency slightly different from that of other ranks. The ear perceives these slight differences, and by simultaneously operating pipes in various ranks, a chorus effect is achieved. An electronic organ may

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have a number of formant circuits, or a number of pickups from a common generator, whereby different voices may be created. But when a flute stop and a diapason stop are simultaneously operated, the voices are not separately perceived; instead they merge to provide a new voice which is neither flute nor diapason. The reason for this is well understood—the electrical signals corresponding to flute and diapason are derived from a common generator, and hence have the identical frequency characteristic, whereas in a pipe organ, this would not be true. In order to remedy this situation, some electronic organs are provided with a plurality of sets of generators, using one set of generators for each voice. The result is quite satisfactory from the performance standpoint, but maintenance, not to mention initial cost, is a substantial problem. Instead of keeping one set of generators tuned, a plurality of sets of generators must be tuned.

Accordingly, another object of this invention is to provide an electronic organ having a plurality of distinct ranks, all driven by a common set of generators. A practical multiple rank electronic organ is thus provided in which all of the ranks are simultaneously tuned by adjustment of the single set of generators. If the organ is of the locked octave type, only twelve generators need be tuned for a multiple rank electronic organ. In order to accomplish this result, I provide a set of phase shifting devices for each added rank desired, the phase shifting devices requiring no adjustment whatsoever. Each set of phase shifting devices has a separate speed characteristic. The multiple rank effect is achieved by adding harmonics to the altered fundamental frequency.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several embodiments of the invention. For this purpose, there are shown a few forms in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a diagrammatic view of an electronic organ incorporating the present invention;

FIG. 2 is a diagrammatic view of a generator and associated frequency shifting apparatus for a single note of the organ;

FIG. 3 is a diagrammatic view similar to FIG. 1, illustrating a modified form of the present invention;

FIG. 4 is a diagrammatic view similar to FIG. 2, illustrating a modified phase shifting device; and

FIG. 5 is a diagrammatic view of an electronic organ, similar to FIG. 1, illustrating another modified form of the present invention.

In FIG. 1 there is illustrated a set of generators **10** corresponding to notes in the musical scale. The individual generators are designated by the notes C_1, $C_1\sharp$, D_1, $D_1\sharp$, E_1, F_1, etc. These generators produce signals the average or nominal frequencies of which are substantially fixed. In the present example, the generators of the set **10** produce sine wave signals, the frequencies of which correspond to the fundamentals of the notes C_1, $C_1\sharp$, D_1, $D_1\sharp$, respectively. Thus the generator C_1 in octave I produces a signal having a nominal frequency of 32.70 cycles per second substantially devoid of signal components of other frequencies. Similarly, the generator $C_1\sharp$ in octave I produces a signal having a nominal frequency of 34.65 c.p.s. The generator C_1 for octave II produces a signal of 65.41 c.p.s., etc. Only a small number of the generators in the entire set is depicted in FIG. 1. These are of course representative of a larger number. For example, there may be generators spanning a musical range of six octaves.

Associated respectively with the generators C_1, $C_1\sharp$, D_1, etc. are individual frequency changing devices 11, 12, 13, 14, etc. respectively diagrammatically depicted. The frequency changing devices 11, 12, 13 and 14 operate upon electrical signals at their input terminals 15, 16, 17 and 18 and translate them into signals having nominal frequencies changed by a predetermined increment. For example, the devices 11, 12, 13, and 14 may be operative to produce a two c.p.s. increase in frequency. Accordingly, at the output terminals 19, 20, 21 and 22, electrical signals exist having frequencies of 34.70 c.p.s., 36.65 c.p.s., 38.71 c.p.s., 40.89 c.p.s., etc. The signals at the output terminals 19, 20, 21 and 22, like the signals at the input terminals 15, 16, 17 and 18, are devoid of harmonics and are substantially sinusoidal in form.

The signals at the output terminals 19, 20, 21 and 22 may be applied to a speaker system 23 through circuits 24, 25, 26, 27, etc., respectively. A common bus bar or connection 28 connected to all of the outputs of the circuits 24, 25, 26, 27, etc. transmits the signals to an amplifier A and the speaker 23, and forms part of a single electrical channel. The circuits 24, 25, 26 and 27 may operate on the sine wave signals to produce signals rich in harmonics and corresponding, for example, to string tones. Thus the circuits 24, 25, 26 and 27 may incorporate high distortion devices, as for example unidirectional conductive devices, and may furthermore incoporate suitable shaping circuits and filter networks. Circuits such as 24, 25, 26 and 27 are well understood in the electronic organ art. Operation of the circuits 24, 25, 26, 27, etc. may be controlled by a common stop 29.

Signals at the output terminals 19, 20, 21 and 22 of the frequency shifting devices 11, 12, 13 and 14 may also be selectively applied to the speaker system 23 respectively through circuits 30, 31, 32, 33, etc. which respectively parallel the circuits 24, 25, 26 and 27. The circuits 30, 31, 32 and 33 may incorporate distorting devices, shaping circuits and filters designed to impart a different characteristic harmonic structure, as for example, a horn tone. The circuits 30, 31, 32 and 33 may be controlled by a common organ stop 34.

Additional circuits and stops may be provided for suitable voicing of the electronic organ.

The devices 24 to 27 and 30 to 33 in a well-understood manner operate upon the signals applied thereto to create harmonics in proper proportionate relationship. Thus the second harmonic of the frequency shifted C_1 signal will have a frequency precisely twice that of the fundamental of the frequency shifted device, namely, 69.40 c.p.s. Accordingly, by shifting the frequency of the fundamentals devoid of their harmonics and thereafter operating upon such frequency shifted signals to create harmonics, the appropriate harmonic relationship is achieved.

Associated with the generators C_1, $C_1\sharp$, D_1, $D_1\sharp$, etc. is another channel (not shown) having circuits corresponding to the circuits 24, 25, 26, 27 . . . and 30, 31, 32, 33 . . . Leads 35, 36, and 37, extending from the generators C_1, $C_1\sharp$, D_1, etc. connect to such channel in which unshifted signals are transmitted.

The frequency shifting devices may be of the form illustrated in FIG. 2. A typical generator structure is also shown for the note C_1. The generator incorporates an electronic emission tube 38 and a tuned grid circuit including an inductance coil 39 and a capacitor 40. The tube 38 is supplied with plate current through a key switch 41. Other keying arrangements and other types of oscillators could, of course, be provided.

Sine wave voltage corresponding to the frequency of the generator assumed to be 32.70 c.p.s. is applied to a bridge circuit including a pair of resistors 42 and 43 and a pair of condensers 44 and 45. Terminals 15*a* and 15*b* correspond to the input terminal 15 of the single

wire diagram of FIG. 1. The terminals 15*a* and 15*b* are connected to the generator so as to derive a sine wave signal therefrom. One branch of the bridge circuit includes the resistor 43 and the condenser 45, and the other branch includes the condenser 44 and the resistor 42. The relative positions of the resistors and condensers are transposed in the branches. At the midterminals 49 and 50 of the bridge circuit the signals are shifted 90° and 270° respectively, providing the capacitive reactance of the condenser 45 (for the frequency in question) equals the resistance of the resistor 43, and further provided that the capacitive reactance of the condenser 44 equals the resistance of the resistor 42. In practice, the resistors 42 and 43 have the same value and the condensers 44 and 45 have the same value.

By the aid of the bridge circuit, terminals 15*a*, 49, 15*b* and 50 are provided that are successively in 90° phase shift relationship with respect to each other. Leads 51, 52, 53 and 54 respectively connect the terminals to stationary segmental plates 55, 56, 57 and 58 of a scanner device. These plates are arrayed equiangularly about a common center. Electrostatically coupled to the plates 55, 56, 57 and 58 is a rotary condenser plate 59 eccentrically mounted about the common axis.

A lead 60 conductively associated with the rotary plate 59, as by the aid of a suitable slip ring structure, provides the output terminal 19. At this terminal 19 signals corresponding to those generated by the oscillator structure exist, but with frequency shifted according to the direction and speed of rotation of the plate 59. A structure of this character is shown and described in "Radio Engineers' Handbook" by Frederick Emmons Terman, First Edition, Second Impression (McGraw-Hill Book Company, Inc., 1943), at page 949. Thus at the output terminal 19, an electrical signal of a frequency of 34.70 c.p.s. exists, providing the rotary plate 59 is moved angularly at the rate of two revolutions per second and in the appropriate direction to produce frequency increase. The amplitude of frequency deviation is controlled by controlling the speed of the plate 59.

Plates corresponding to the plate 59 of all the frequency shifting devices 11, 12, 13, 14, etc. many be operated by a common motor M shown in FIG. 1. The motor M may have associated therewith a suitable adjustable transmission such that the frequency deviation may be controlled.

A different type of phase shifting device is illustrated in FIG. 4. Four light sensitive resistors R1, R2, R3 and R4 are star connected with the common central terminal forming the output terminal 19. The outer terminals of the resistors are respectively connected to the terminals 15*a*, 15*b*, 49 and 50 of the phase splitting bridge circuit like that illustrated in FIG. 2. Thus, impressed across the resistors R1, R2, R3 and R4 are signals having the same frequency, but successively shifted 90°.

A rotary shutter S intercepts a field of uniform illumination otherwise incident upon the resistors. An aperture in the shutter successively exposes the resistors, resulting in decreased resistance and increased coupling of the corresponding resistor to the output terminal 19. Accordingly, the signal is shifted in frequency.

By properly shaping the shutter aperture, the output waveform can be made sinusoidal.

Apparatus of this type is shown and described in United States Letters Patent No. 3,086,122, to E. M. Jones, issued April 16, 1963.

The frequency shifting devices 11, 12, 13 and 14 can be grouped for operation by different motors so as to avoid a certain "sameness," and thus more truly simulate the pipe organ characteristic. By causing the devices 11, 12, 13, 14, etc. to produce a slightly sharp frequency, a celeste type effect is achieved. By causing the devices 11, 12, 13, 14, etc. to provide very slight frequency changes in either direction, a chorus effect may be achieved.

In the form of the invention illustrated in FIG. 3, four electrical acoustic channels **61, 62, 63** and **64** are provided for the frequency altered signals. In the electrical acoustic channel **61**, signals exist corresponding to notes C, D, E, F#, G#, A# for alternate octaves, as for example, octaves numbered I, III, etc. In the electrical acoustic channel **62**, signals exist corresponding to notes C#, D#, F, G, A, B for alternate octaves, as for example, those numbered I, III, etc. In the electrical acoustic channel **63**, signals exist corresponding to notes C, D, E, F#, G#, A# to the alternate octaves corresponding to those numbered II, IV, etc. And in the electrical acoustical channel **64**, signals exist corresponding to notes C#, D#, F, G, A, B in the said other alternate octaves, that is, those numbered II, IV, etc.

Furthermore, freqency shifting devices **65, 66, 67, 68, 69**, etc. are divided into four groups, one group being provided for notes whose signals are transmitted to the channel **61**, another for the signals corresponding to notes for the channel **62**, another group for notes corresponding to signals transmitted in the channel **63**, and finally another group for notes corresponding to signals in the channel **64**. Motors **70, 71, 72** and **73** are provided for operating the scanners of the groups at different rates and perhaps in different directions depending upon the effect desired. In place of separate motors **70, 71, 72** and **73**, separate output shafts may be provided from a common transmission mechanism.

Any other grouping of the frequency shifting devices may be provided. If the number of groups frequency shifting devices is increased, there will be an increased chance that notes simultaneously sounded will have their frequencies changed by different amounts. However, a grouping of four is quite effective, especially where frequency shifting devices for alternate notes and alternate octaves are separated. Thus, for example, should the organist play a simple chord corresponding to A_7, beginning in Octave I, A_1 will have its frequency altered in accordance with the setting of the motor **71**; $C\#_2$ will have its frequency alternated in accordance with the setting of the motor **73**; E_2 will have its frequency altered in accordance with the setting of the motor **72**; and G_2 will have its frequency altered in accordance with the setting of the motor **73**.

By virtue of the segregation of signals corresponding to alternate notes in alternate octaves into separate electrical acoustic channels **61, 62, 63** and **64**, the possibility of beat effects occurring, either due to the mistuning of notes in octave relationship or due to notes in fourth and fifth interval musical relationship, is substantially minimized. Thus, for example, C_1 may have its frequency altered to 34.70 c.p.s, and the second harmonic created by the circuit structures associated with the organ stops will accordingly be 69.40 c.p.s. This frequency will necessarily be different from the alternated frequency of the fundamental of C_2. Accordingly, if signals corresponding to the second harmonic of C_1 and the fundamental of C_2 were sounded in the same electrical channel, such signals would move into and out of reinforcing relationship with respect to each other at a rate corresponding to the difference in frequency. This would normally create an annoying beat effect. The possibility of such electrical interaction is precluded since the second harmonic C_1 exists in the channel **61**, and the fundamental of C_2 exists in the channel **63**. Similarly, by virtue of the alternate note separation, the possibility of beat effects due to simultaneously sounding notes in fourth or fifth interval musical relationship is avoided and as explained in further detail in my prior Patent No. 2,596,258.

A multirank organ is illustrated in FIG. 5. Three electrical channels **82, 83** and **84** form three different ranks. In the present instance, each channel has associated therewith an amplifier **85, 86** and **87** and a speaker **88, 89** and **90**. If desired, the electrical channels **82, 83** and **84** can be combined.

Associated with the electrical channel **82** is a set of phase shifting devices **91, 92, 93** . . . , all driven by a motor **94**. The phase shifting devices have input terminals respectively connected to the output of sine wave generators C, C#, D. . . . At the output terminals of the phase sihfting devices **91, 92, 93** . . . , sine wave signals corresponding to the notes C, C#, D, D#, . . . are shifted in frequency by an amount corresponding to the speed and direction of the motor **94**. The output terminals of the phase shifting devices **91, 92, 93** . . . are connected to the electrical channel **82** through voicing circuits **95, 96, 97** . . . respectively. Each of the voicing circuits **95, 96, 97** . . . may be composite circuits cooperable with suitable organ stops to add desired harmonic characteristics.

A second set of phase shifting devices **98, 99, 100** . . . provide frequency altered signals for a second electrical channel **83**. The phase shifting devices **98, 99, 100** . . . are all driven by a motor **101** and at a speed perferably slightly different from the speed that the motor **94** drives the phase shifting devices **91, 92, 93** . . . of the first set. The input terminals of the phase shifting devices **98, 99, 100** . . . are also connected to the outputs of the generators C, C#, D, D#, E. . . . The output terminals of the phase shifting devices **98, 99, 100** . . . are connected to the electrical channel **83** through voicing circuits **101, 102, 103** . . . that impart a suitable harmonic characteristic to the frequency altered tones.

The third electrical channel **84** similarly has a set of phase shifting devices **104, 105, 106** . . . also actuated by the sine wave generators C, C#, D, D#. . . . A motor **107** operates all of the phase shifting devices **104, 105, 106** . . . and at a rate different from the speed of the operation of other sets of phase shifting devices. Voicing circuits **108, 109, 110** . . . connect the output terminals of the phase shifting devices to the electrical channel **84**.

The sets of voicing circuits may all be of the same type, each, for example, having the capabilities of producing flute, string, horn, diapason or other tones upon operation of suitable organ stops. Optionally, the voicing circuits may have different capabilities. The electrical channels **82, 83** and **84** provide distinct ranks, each with their separate frequency characteristics. Thus the signal in the electrical channel **82** corresponding to C# has a frequency slightly different from the signals in channels **83** and **84** for notes corresponding to C#. Sounds produced by the signals in the electrical channels **82, 83** and **84** thus are distinctly perceived. As many ranks, that is, electrical channels **82, 83** and **84** together with sets of phase shifting devices and voicing circuits may be provided as desired.

Tuning of the generators C, C#, D, D#, E . . . automatically accomplishes tuning of all the ranks or channels **82, 83** and **84**. The speed of the motors **94, 101** and **107** may be adjusted if desired. Preferably their speeds are random.

In the systems shown in FIGS. 1, 3 and 5, the frequency shifting devices are operatively associated with the sine wave form of the signals, and distortion, shaping and filtering circuits operate upon the altered frequencies. By virtue of this arrangement, the degree of sharpness or flatness throughout the musical spectrum can be substantially constant, all while maintaining the proper proportionate relationship of harmonics.

The inventor claims:

1. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; a frequency shift channel having means shifting the nominal frequency of signals applied thereto; means for deriving electrical signals from said generators and applying them to said shift channel; and means operatively associated with said shift channel for adding harmonics to the signals shifted in frequency.

2. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical

signals corresponding to notes in a musical range; a pair of electrical output channels; circuit means for imparting harmonic content to the signals of said channels; first means for connecting said generators to one of said channels; second circuit means for connecting said generators to the other of said channels; and means interposed in said one of said circuit means for shifting the nominal frequency of the signals therein.

3. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; circuit means for adding harmonics to signals; and means for connecting the generators to the circuit means, including means for altering the nominal frequency of the signals.

4. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; a pair of separate output channels; a first set of circuits between generators corresponding to alternate half tones and one of said channels; a second set of circuits between the generators corresponding to the other alternate half tones and the other of said channels; said circuits each including means for shifting the frequency of the signals and means for imparting harmonics to the nominal frequency shifted signals.

5. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; a pair of separate output channels; a first set of circuits between generators corresponding to alternate half tones and one of said channels; a second set of circuits between the generators corresponding to the other alternate half tones and the other of said channels; said circuits each including means for shifting the nominal frequency of the signals and means for imparting harmonics to the frequency shifted signals; the frequency shifting means of one set of circuits producing a frequency deviation different from the frequency deviation of the frequency shifting means of the other set of circuits.

6. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; and a circuit between each of the generators and the output channel including means for shifting the nominal frequency of the generated signal, and means for imparting harmonics to the frequency shifted signal.

7. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; and a circuit between each of the generators and the output channel including rotary means for shifting the nominal frequency of the generated signal in accordance with the direction and speed of operation of said rotary means, said circuit further including means for imparting harmonics to the frequency shifted signal.

8. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; a circuit between each of the generators and the output channel including rotary means for shifting the nominal frequency of the generated signal in accordance with the direction and speed of operation of said rotary means, said circuit further including means for imparting harmonics to the frequency shifted signal; first power means for operating a group of rotary means; and second power means for operating another group of

rotary means; said power means having differing speed characteristics.

9. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; a circuit between each of the generators and the output channel including rotary means for shifting the nominal frequency of the generated signal in accordance with the direction and speed of operation of said rotary means, said circuit further including means for imparting harmonics to the frequency shifted signal; a plurality of power means for operating a corresponding plurality of groups of rotary means, each of said power means having its own speed characteristic.

10. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; a circuit between each of the generators and the output channel including rotary means for shifting the nominal frequency of the generated signal in accordance with the direction and speed of operation of said rotary means, said circuit further including means for imparting harmonics to the frequency shifted signal; a plurality of power means for operating a corresponding plurality of groups of rotary means, each of said power means having its own speed characteristic; one group including rotary means for circuits corresponding to C, D, E, F♯, G♯ and A♯ in alternate octaves, a second group including rotary means for circuits corresponding to C, D, E, F♯, G♯ and A♯ in the other alternate octaves, a third group including rotary means for circuits corresponding to C♯, D♯, F, G, A and B in alternate octaves, and a fourth group including rotary means for circuits corresponding to C♯, D♯, F, G, A and B in the other alternate octaves.

11. The combination as set forth in claim 10 in which said output channel has four parts for the circuits corresponding to the respective groups.

12. In an electrical musical instrument: a set of substantially sine wave generators for producing electrical signals corresponding to notes in a musical range; an output channel; a circuit between each of the generators and the output channel including rotary means for shifting the nominal frequency of the generated signal in accordance with the direction and speed of operation of said rotary means, said circuit further including means for imparting harmonics to the frequency shifted signal; a plurality of power means for operating a corresponding plurality of groups of rotary means, each of said power means having its own speed characteristic; one group including the rotary means for circuits corresponding to C, D, E, F♯, G♯ and A♯, and another group including the rotary means for circuits corresponding to C♯, D♯, F, G, A and B.

13. The combination as set forth in claim 12 in which said output channel has two parts for the circuits corresponding to the respective groups.

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