March 5, 1968 D. J. LESLIE 3,372,225

ELECTRONIC MUSICAL INSTRUMENT INCORPORATING ROTARY
ELECTROSTATIC DEVICES FOR PRODUCING
CELESTE OR CHORUS EFFECTS

Filed March 10, 1964 4 Sheets-Sheet 1

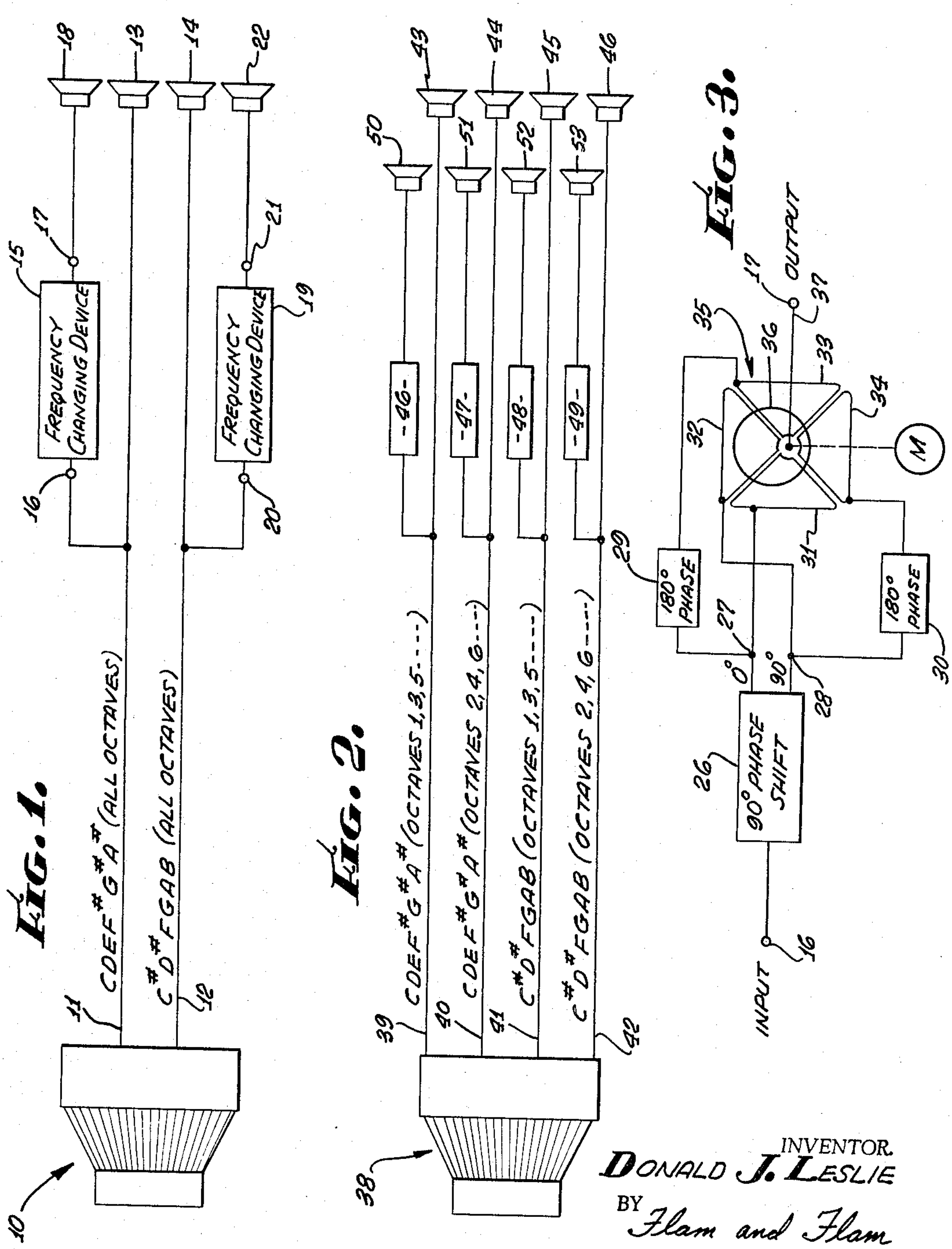

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FIG. 1a.

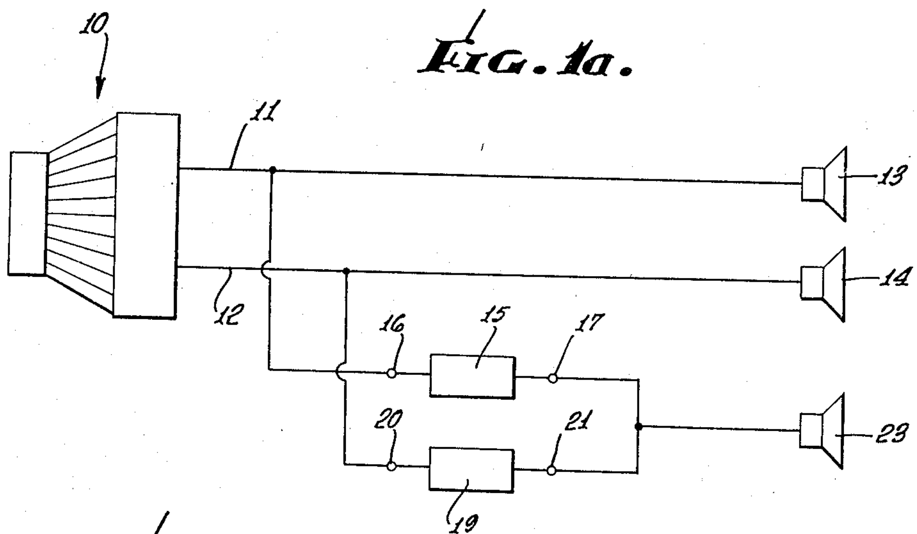


FIG. 1b.

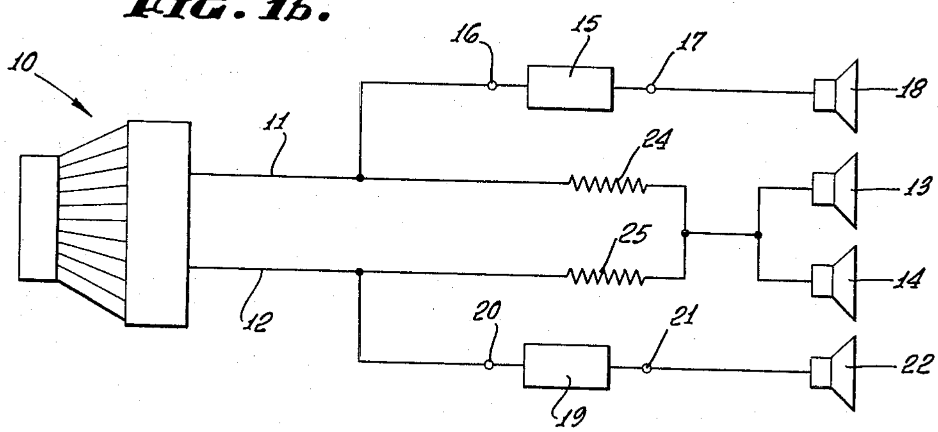
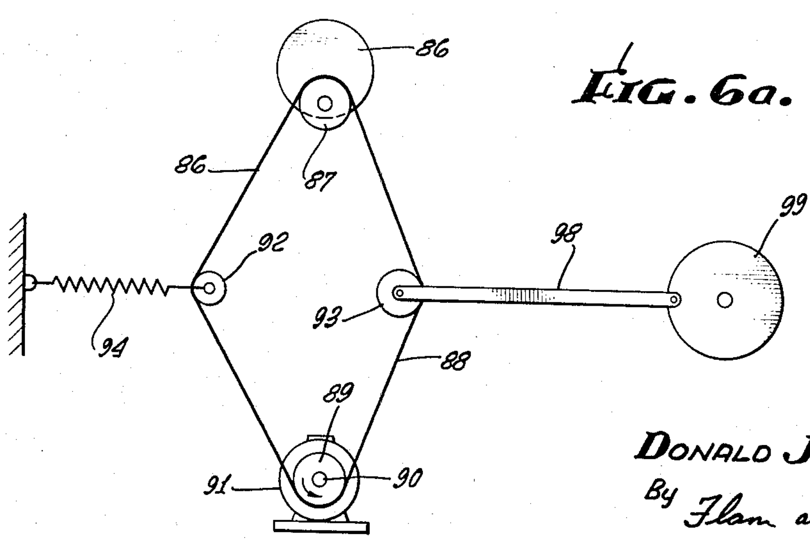


FIG. 6a.



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ELECTRONIC MUSICAL INSTRUMENT INCORPORATING ROTARY ELECTROSTATIC DEVICES FOR PRODUCING CELESTE OR CHORUS EFFECTS

Filed March 10, 1964 4 Sheets-Sheet 3

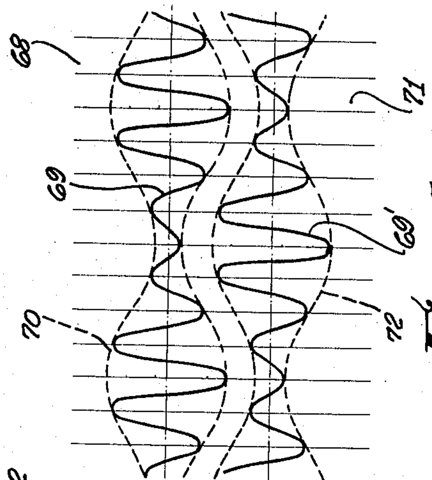

FIG. 4a.

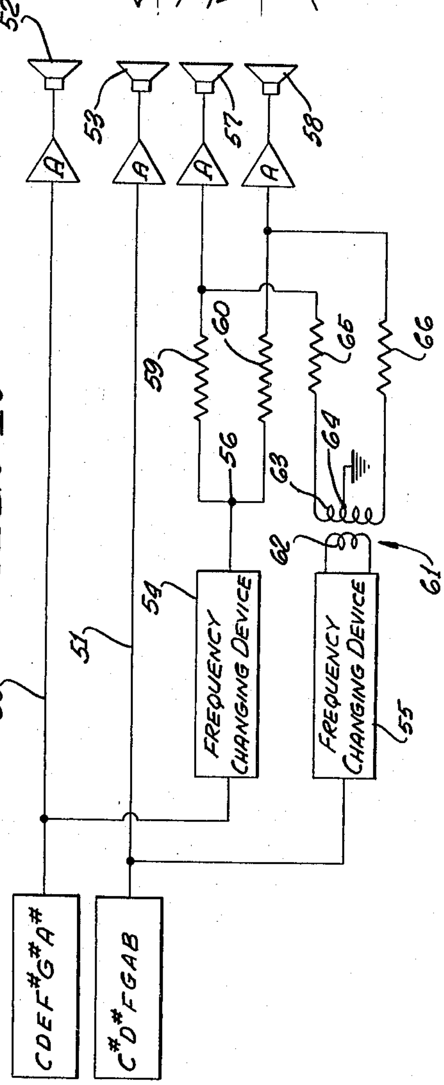

FIG. 4.

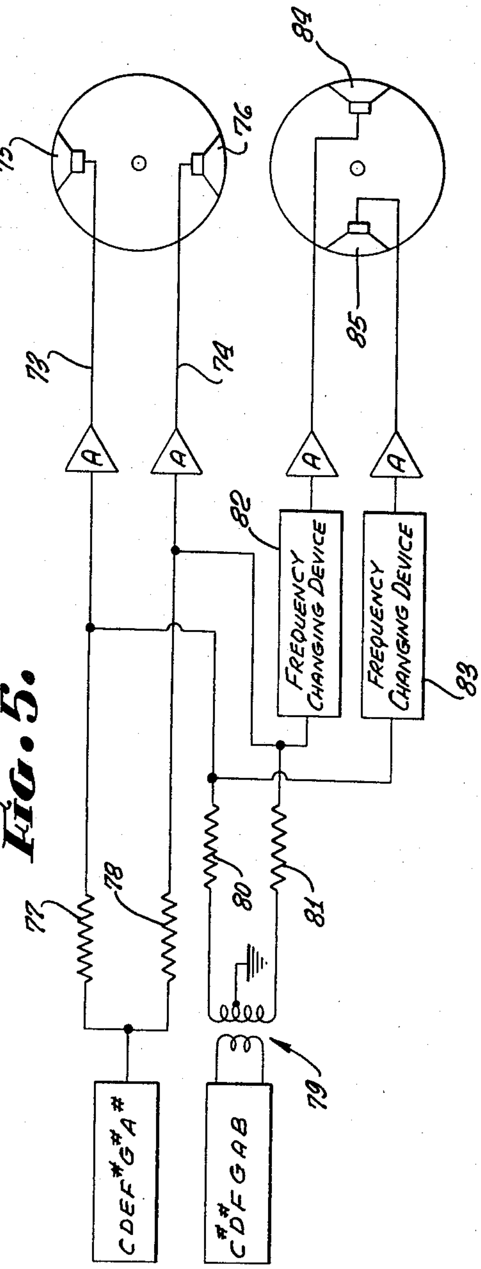

FIG. 5.

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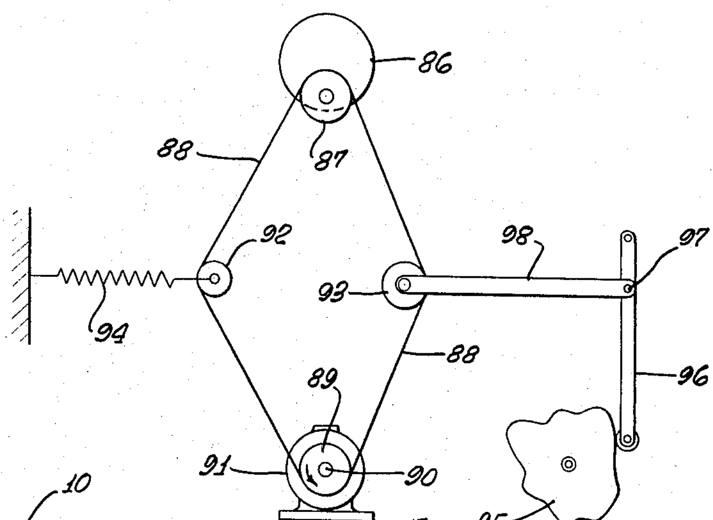
FIG. 6.



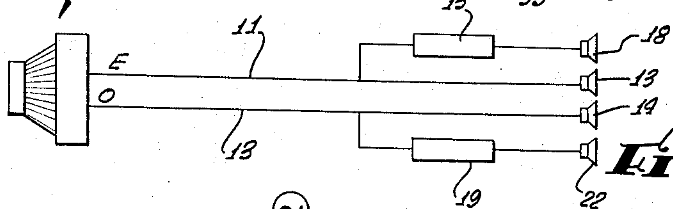


FIG. 9.

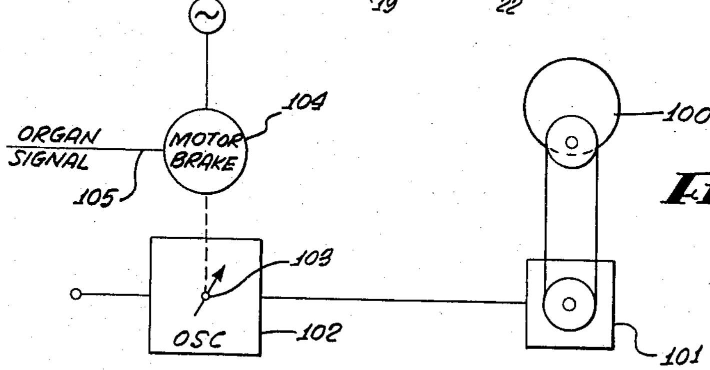
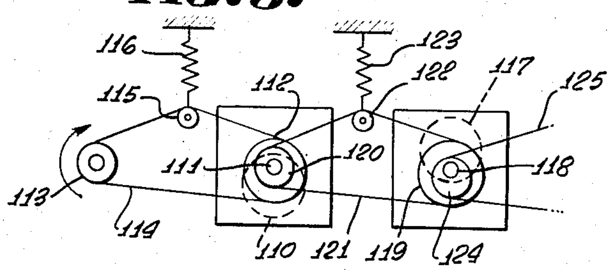


FIG. 7.

FIG. 8.



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ELECTRONIC MUSICAL INSTRUMENT INCORPORATING ROTARY ELECTROSTATIC DEVICES FOR PRODUCING CELESTE OR CHORUS EFFECTS

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Filed Mar. 10, 1964, Ser. No. 350,717
53 Claims. (Cl. 84—1.24)

ABSTRACT OF THE DISCLOSURE

In order to produce a celeste or chorus effect, auxiliary electrical-acoustic channels are derived from the main channels of the electronic organ. One auxiliary channel, including a frequency changing device 15, suitable amplifiers and a speaker 18, derives signals from one organ output 11 at which impulses corresponding to notes C, D, E, F#, G# and A# exist. The other auxiliary channel, including the frequency changing device 19, suitable amplifiers and a speaker 22, derives signals from the other organ output 12 at which impulses corresponding to notes C#, D#, F, G and B exist. Each frequency changing device (FIG. 3) includes a rotary electrostatic plate 36 cooperable with stationary plates 31, 32, 33 and 34 at which the impulses respectively exist in equiangularly spaced phase shift relationship. Motive means M drives the plate 36 at a variable or random rate such as by the device shown in FIGS. 6, 6*a*, 7 and 8.

Background of the invention

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

Those skilled in the design of electronic organs are well versed in the arts of determining the characteristics of electrical impulses so as to achieve any desired formant and harmonic characteristic. Yet however versatile the associated controls and circuits may be, a single set of generators produces essentially only one voice at a time. But a pipe organ (except one of the most elementary type) has a plurality of pipe ranks, and thus has the capability of producing a number of distinct sounds at the same time. The pipes of different ranks corresponding to the same note cannot have precisely the same tuning and thus their sounds move into and out of phase relationship, and the listener hears different pipes simultaneously. Of course a similar effect could be obtained in an electronic organ by providing a plurality of sets of generators. But this is not always practical. Various attempts have been made to utilize phase electrical circuits in association with a single set of generators whereby an auxiliary set of generators is created for chorus or celeste purposes. This may be done, for example, by heterodyne circuits or the like, and as suggested in a U.S. Patent to William C. Wayne, Jr., No. 3,004,460, issued Oct. 17, 1961, and entitled "Audio Modulation System."

Devices of this character, though seemingly sound in theory, nevertheless fail to produce a recognizable chorus or celeste effect. Instead, annoying slow beating effects and unusual amplitude changes dominate to the point where the chorus or celeste effect is not perceived. This undesirable effect is present even in organizations where the altered signals are provided with a separate electrical acoustic channel.

The problem exists because beat effects are compounded. Thus the original electrical channel contains the source of certain beat effects due to the harmonics of fourth and fifth interval notes, and harmonics of notes in octave relationship where generators for notes in octave relationship are not locked togther. Furthermore, the very process of frequency shifting to create the altered rank produces a beating problem since the proportionate tuning is disturbed. Consequently, beat effects are engrafted upon beat effects, and the result is unmusical.

The primary object of this invention is to provide a means whereby known frequency shifting devices can be effectively utilized to produce a distinct chorus or celeste effect.

It has been proposed to use a frequency shifting device in conjunction with all notes in a substantial band. This results in a constant degree of deviation from true pitch and a noticeable lack of similitude to the pipe organ. Thus in a pipe organ the pitch deviation of the pipes in a celeste rank is not constant. Accordingly, another object of this invention is to provide a simple system whereby the pitch deviation of notes simultaneously sounded differ, thus more perfectly simulating the pipe organ characteristic.

Another object of this invention is to provide apparatus of this character in which the pitch deviation is constantly changed in order to avoid a certain sameness to the musical effect.

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 detail description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Brief description of the drawings

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

FIGS. 1*a* and 1*b* are diagrammatic views, each showing a modified form of the present invention;

FIG. 2 is a diagrammatic view similar to FIG. 1, illustrating another modified form of the present invention;

FIG. 3 is a diagrammatic view of a typical frequency shifting device usable in the system shown in FIGS. 1, 1*a*, 1*b* and 2;

FIG. 4 is a diagrammatic view similar to FIG. 1, illustrating another modified form of the present invention;

FIG. 4*a* is a graphical representation illustrating the amplitude of sounds issuing from two of the speakers of FIG. 4;

FIG. 5 is a diagrammatic view similar of FIG. 4, illustrating another modified form of the present invention;

FIGS. 6, 7 and 8 are diagrammatic views each illustrating a device for achieving a constantly changing pitch deviation;

FIG. 6*a* is a diagrammatic view showing a modified form of the present invention; and

FIG. 9 is a diagrammatic view similar to FIGS. 1, 2, 4 and 5, illustrating another modified embodiment of the present invention.

Detailed description

In FIG. 1 there is illustrated an electronic organ 10 in which two separate electrical output channels 11 and 12 are provided. The organ 10 is so wired that when the organist plays a key corresponding to C, D, E, F♯, G♯ or A♯, the electrical impulses corresponding to such notes are translated in the electrical channel 11 substantially or entirely to the exclusion of the electrical channel 12. Similarly, should the organist play a key corresponding to C♯, D♯, F, G, A or B, the electrical impulses corresponding to those notes are translated in the electrical channel 12 substantially or entirely to the exclusion of the electrical channel 11. Such an arrangement is shown and described, for example, in my prior Patent No. 2,596,258, issued May 13, 1952, and entitled "Electric Organ Speaker System."

The electrical channels 11 and 12 are indicated by single leads, the ground leads not being illustrated for purposes of clarity. Directly cooperable with the respective electrical channels 11 and 12 are speakers 13 and 14 by the aid of which the electrical impulses are translated into sound. Associated with the electrical channels 11 and 12 may be suitable amplifiers (not shown).

A frequency changing device 15 operates to shift all frequencies by a predetermined amount, for example by increasing the frequencies by two cycles per second. Thus, for example, if a frequency component of 261.63 c.p.s. (corresponding to C_4) exists at the input terminal 16 to the frequency changing device 15, then that component will appear at the output terminal 17 thereof with a frequency of 263.63 c.p.s. Furthermore, the second harmonic of C_4 and having a frequency of 523.25 c.p.s. at the input terminal 16 will appear at the output terminal 17 with a frequency of 525.25 c.p.s.

The input terminal 16 is connected to the channel 11 so as to be actuated thereby, and the output terminal 17 is connected to a speaker 18 for translating such frequency altered signals into sound.

A frequency changing device 19, similar to the device 15, has an input terminal 20 connected to the electrical channel 12, and has its output terminal 21 connected to a separate speaker 22.

The frequency changing devices 15 and 19 preferably produce slightly different pitch deviations. Thus, for example, the device 15 may produce an increment of two c.p.s. in connection with each component existing at the input terminal 16, and the frequency changing device 19 may produce an increment of one and a half c.p.s. The devices 15 and 19 may both produce frequency increases, or both produce frequency decreases, or one of them may produce a frequency increase while the other produces a frequency decrease.

The electrical channels 11 and 12 are each free of beat effects due to the simultaneously sounding notes in fourth or fifth musical interval relationship with respect to each other, all as described in my said prior Patent No. 2,596,258. Furthermore, the organ 10 shown in FIG. 1 is assumed to be of a type in which generators in octave relationship are locked together so that their relative tuning remains invariant. Thus no beat effects exist in the channels 11 and 12 due to mistuning of generators in octave relationship. Accordingly, the frequency shifting devices 15 and 19 respectively operate with channels in which there are no appreciable beat effects, and the beat effects added by the frequency changing devices 15 and 19 do not compound existing beat effects. The overall result is a clearly descernible celeste or chorus effect.

I have found that a chorus effect also exists when the output terminals 17 and 21 of the devices 15 and 19 are connected together for driving a common speaker system 23 as shown in FIG. 1*a*, as long as separate speakers 13 and 14 are provided for the main channels 11 and 12. Furthermore, I have found that a significant celeste or chorus effect exists when the channels 11 and 12 are connected together, as in FIG. 1*b*, for driving a common speaker system 13–14. In this instance, however, the channels 11 and 12 are connected together in such manner as to maintain isolation of the respective frequency changing devices 15 and 19. Resistors 24 and 25 are provided in the channels 11 and 12 for such isolation purposes.

When a chord is played (other than an augmented or equivalent chord) impulses are produced in both electrical channels 11 and 12. This means that certain components of the chord are acted upon differently so far as frequency alteration is concerned. Thus, for example, if a major chord, C, E and G, is sounded, the G component will have its frequency altered in accordance with the setting of the device 19 which is different from the frequency alteration of the notes C and E by virtue of the operation of the frequency changing device 15. A certain "sameness" to the frequency alteration is thus avoided and an effective simulation of pipe organ characteristics is achieved.

The frequency shifting devices 15 and 19 may be of a type shown and described in a patent to William C. Wayne, Jr., No. 3,004,460, above identified. Optionally, the devices 15 and 19 may be of a type diagrammatically illustrated in FIG. 3. In FIG. 3, a wide band 90° phase shifting device 26 is shown that provides two output terminals 27 and 28. The signal at output terminal 27 may be considered as having a 0° phase shift. The signal at the ouput terminal 28 relative to terminal 27 is advanced in phase by 90°. Such a 90° phase shift device, operable over an adequately wide band is shown and described, for example, in the American Radio Relay Handbook, Thirtieth edition (1953), at page 298. Inverters or 180° phase shifting devices 29 and 30, operable in conjunction with the output terminals 27 and 28, make it possible to achieve four outputs in zero, 90°, 180° and 270° relationship with respect to each other. Such outputs are applied to four equiangularly arrayed stationary plates 31, 32, 33 and 34 of a frequency changing device 35. The frequency changing device 35 may be of the type shown and described in Radio Engineers' Handbook by Frederick Emmons Terman, First edition, second impression (1943), at page 949. The device 35 has a circular rotary plate 36 eccentrically mounted with respect to the center of the stationary plates 31, 32, 33 and 34. A motor M rotates the plate 36 at a rate and in a direction corresponding to the desired frequency shift. A lead 37 connects with the rotating plate through a suitable slip ring structure (not shown) and provides the output terminal 17.

If a frequency component F is applied to the terminal 16, it appears at the output 17 with a frequency $(f+\Delta f)$, Δf corresponding to the speed of the motor M in cycles per second.

In the form of the invention illustrated in FIG. 2, an organ 38 is illustrated that is assumed to have a separate generator for notes in octave relationship with respect to each other. In such circumstances, there is a possibility of beat effects due to relative mistuning of generators in such octave relationship. In order to provide electrical channels relatively free of beat effects due to fourth or fifth interval interaction, as well as interaction of impulses in octave relationship with respect to each other, the organ is so wired to provide four electrical channels 39, 40, 41 and 42. In the channel 39 impulses corresponding to C, D, E, F♯, G♯, and A♯ exist for alternate octaves, and in the electrical channel 40 impulses corresponding to these notes exist at the other alternate octaves. The electrical channels 41 and 42 similarly operate in conjunction with the alternate notes C♯, D♯, F, G, A and B, as indicated in the drawings. The octave separation may occur at any convenient place, as for example between B and C. In such circumstances, should the organist sound a simple chord corresponding to A major and beginning at octave No. 2, impulses corresponding to A will exist the channel 42, impulses corresponding to C♯ in octave No. 3 will exist in the electrical channel 41, and impulses corresponding to E in octave No. 2 will exist in the electrical channel 40. There is thus an increase probability of chords existing in separate electrical channels due to the further segregation.

Impulses corresponding to notes in successive octave relationship with respect to each other must necessarily exist in separate electrical channels. Accordingly, electrical interaction is precluded, and the possibility of beat effects is minimized. Similarly, by virtue of the alternate note segregation, beat effects due to notes in fourth and fifth musical interval relationship is avoided. Thus, the electrical channels 39, 40, 41 and 42 contain no substantial inherent beat effects.

Speakers 43, 44, 45 and 46 are actuated directly by the electrical channels 39, 40, 41 and 42, suitable amplifiers (not shown) being provided as necessary. Operatively associated with each of the channels 39, 40, 41 and 42 are frequency changing devices 46, 47, 48 and 49 which may be of a type illustrated in FIG. 3. Speakers 50, 51, 52 and 53 translate the altered frequencies into sound. The devices 46–49 may be individually set to provide separate pitch deviations. Since the devices 46–49 are connected to electrical channels having no significant beat effect problem, there is no compounding of beat effects and a rich celeste or chorus effect is perceived.

In the form of the invention illustrated in FIG. 4, the electronic organ has output leads 50 and 51. At the lead 50 impulses corresponding to C, D, E, F♯, G♯ and A♯ exist and at the lead 51 impulses corresponding to C♯, D♯, F, G, A and B exist as in connection with the form illustrated in FIG. 1. Speakers 52 and 53 directly cooperate with the leads 50 and 51.

A pair of phase shift devices 54 and 55 similar to the device illustrated in FIG. 3 respectively derive impulses from the channels 50 and 51 in order to produce altered frequencies. Phase shift device 54 has an output terminal 56 at which impulses corresponding to C, D, E, F♯, G♯ and A♯ exist. The output from the phase shift device 54 is applied equally to two speakers 57 and 58 through suitable isolation resistors 59 and 60.

The phase shift device 55 drives the primary winding 61 of an output transformer 62. The secondary winding 63 has a center tap 64 connected to ground or common, and dividing the secondary winding into two sections.

The frequency altered signals exist across both sections of the secondary winding 63 but in 180° phase shifted relationship. One terminal of the secondary winding 63 connects to the speaker 57 through an isolation resistor 65 and the other terminal connects to the speaker channel 58 through an isolation resistor 66. In the channel for the speaker 57, certain beat effects exist due, for example, to the interaction of frequencies corresponding to notes in fourth or fifth musical interval relationship. Thus, for example, impulses corresponding to D (661.26 c.p.s.) are applied to the speaker 57 via phase shifting device 54, and impulses corresponding to A (442 c.p.s.) are applied to the same speaker 57 via phase shifting device 55. The third harmonic of A (442 c.p.s.) has a frequency of 1326 c.p.s., and the second harmonic of D (661.26 c.p.s.) has a frequency of 1324.56 c.p.s. These components beat with each other. Thus, at the graph 68 (FIG. 4*a*) there is depicted a sinuous wave 69 resulting from the combination of these beating components. These components move into and out of reinforcing relationship with respect to each other at a rate corresponding to the difference in their frequencies, namely 1.44 c.p.s. A modulation envelope 70 defines the cyclic increase and decrease of amplitude of the resultant combined wave form 69.

Similarly, in the channel associated with the speaker 58, a graph 71 (FIG. 4*a*) depicts the frequency component 69′ produced by the same impulses that produce the wave form 69. However, in this instance, one of the components, namely A (442 c.p.s.), is shifted in phase by 180°. This means that when the impulses reinforce each other in the channel associated with the speaker 59, they oppose each other in the channel 71. Consequently, the modulation envelope 72 is interspaced with the modulation envelope 70. The ear hears both beat effects simultaneously, but these two beat effects complement each other to produce a sound having a fairly constant amplitude. The beat effect is minimized. Whatever beat effects exist in one channel exist equally in the other channel, but in out of phase relationship.

This arrangement is shown an described in my prior Patent No. 3,049,040, issued Aug. 14, 1962, and entitled "Apparatus For Minimizing Beat Effects." Beat effects

caused by the characteristics of the tempered scale are not compounded with beat effects due to the alteration of frequency by the phase shift devices 54 and 55 and a well-defined celeste effect is achieved.

Furthermore, in this organization, there is a substantial balance of the impulses between the speakers 57 and 58. Thus, whatever impulse exists in the speaker 57, likewise exists in the speaker 58.

In the form of the invention illustrated in FIG. 5, a similar arrangement is provided. However, in this instance, the criss-crossing is applied to main electrical channels 73 and 74 associated with speakers 75 and 76. Thus, the organ output for impulses corresponding to C, D, E, F♯, G♯ and A♯ are applied equally to the channels 73 and 74 through isolation resistors 77 and 78. The organ output for impulses corresponding to C♯, D♯, F, G, A and B are applied equally to the channels 73 and 74 but in 180° phase shifted relationship. For this purpose, a transformer structure 79 is provided. Isolation resistors 80 and 81 connect opposite ends of the transformer 79 to the channels 73 and 74. The arrangement as thus far described in substantially similar to that illustrated in FIG. 2 of said prior Patent No. 3,049,040.

Phase shifting devices 82 and 83 respectively cooperate with the channels diagrammatically illustrated at 73 and 74 and alter the frequency impulses. These phase shift devices 82 and 83 operate speakers 84 and 85. Speakers 75 and 76 translate all unaltered impulses, and speakers 84 and 85 translate all frequency altered impulses. Beat effects of speaker 75 largely cancel out beat effects of speaker 76. Phase shifting devices 82 and 83 each operate on all impulses, and cause the speakers 84 and 85 to produce beat effects, but beat effects due to fourth and fifth interval interaction substantially cancel out since, due to transformer 79, such beat effects in speaker 84 are out of phase with those of speaker 85.

The speakers 75, 76, 84 and 85 are all mounted upon a common acoustic tremolo drum which is rotated constantly at the rate of approximately 3½ revolutions per second. The speakers 75 and 76 for the main channel are located 180° apart on the drum and similarly the speakers 84 and 85 for the frequency altered or celeste impulses are mounted 180° apart. The sound radiation pattern of impulses recurs at the rate of approximately seven cycles per second since the frequencies produced by speakers 84 and 85 are different from those produced by speakers 75 and 76. Accordingly, characteristic tremolo or vibrato of about seven cycles per second is imparted to the sounds. Channels 73 and 74 will be understood as including slip rings or equivalent devices.

In FIG. 6 there is diagrammatically illustrated apparatus for rotating the revolving plate 86 of the phase shifting device such as illustrated in FIG. 3 at a variable rate. By so doing, the frequency deviation will be variable, and a close simulation of the characteristics of pipe organs will be achieved.

Plate 86 is shown as having a driving pulley 87. This driving pulley connects with an endless belt 88 engaging a pulley 89 mounted upon the output shaft 90 of a motor 91. The shaft 90 may operate at a speed of approximately 120 revolutions per minute. Idler pulleys 92 and 93 engage opposite runs of the belt 88 between the driving pulley 89 and the driven pulley 87. The idler pulley 92 is urged by a spring 94 to tension the belt 88. The idler pulley 93 is moved in an irregular manner by the aid of the cam 95. Cam 95 engages a rocker arm 96 that is pivotally connected as at 97 to a rod 98 for moving the pulley 93 in a substantially linear path.

When the idler pulley 93 is stationary, the motion of the motor pulley 89 is transmitted directly to the pulley 87. However, when the belt 88 is pulled to the right, and assuming belt motion in the arrow direction, the speed of the belt 88 at the pulley 87 is momentarily reduced. Hence the frequency shift produced by the plate 86 is a direct function of the velocity of movement of the rod 98.

The cam 95 has an irregular configuration so as to produce various velocities for the movement or rod 98.

In place of a cam 95, a crank 99 (FIG. 6a), can be provided for reciprocating the rod 98. The rod 98 then undergoes a sinusoidal movement, and a corresponding change of speed of operation of the pulley 87.

In the form of the inventin illustrated in FIG. 7, the rotary plate 100 of the phase shift device is operated by a motor 101 energized from a variable frequency source or oscillator 102. The oscillator 102 includes a circuit element that is variable in accordance with the angular position of a shaft 103. This impedance element affects the frequency of oscillation of the oscillator 102 so as to change the synchronous speed of the motor 101 and thus affect a change in the frequency shift.

The shaft 103 may be capable of achieving a range of motor speeds within the range of approximately 80 to 160 revolutions per minute. The shaft 103 is operated by a motor brake unit 104 that is controlled by an organ signal through a lead 105 and in a manner shown and described in my copending application Ser. No. 862,313 entitled "Pitch Broadening Apparatus for Musical Instruments Having Electronic Tone Generators," filed Dec. 29, 1959, now Patent No. 3,146,291 issued Aug. 25, 1965. Thus as the organist operates any pedal, for example, signal is applied to the lead 105 so as to actuate the motor brake unit 104, causing the shaft 103 to turn. When the pedal is released, the device 104 stops the movement of the shaft 103. When the same or different pedal is played, the motor 104 again operates. In this manner the speed of the motor 101 is random and accordingly a sameness in the frequency change is avoided.

In the form of the invention illustrated in FIG. 8, there is shown a rotary plate 110 that may form a part of the phase shift device as shown, for example, in FIG. 3. Mounted upon the shaft 11 for the plate 110 is a noncircular transmission member, in this instance in the form of an eccentric pulley 112.

A driving pulley 113, rotated at a constant speed of approximately three revolutions per second, operates the eccentric pulley 112. For this purpose, a belt 114 is provided that connects the pulleys. Interposed in the upper run of the belt is an idler pulley 115 that maintains suitable belt tension through the action of the spring 116. The driving pulley 113 is rotated in the arrow direction so as to impart constant lineal speed to the lower run of the belt. As the pulley 112 is rotated, the belt 114 acts at a changing radius and accordingly imparts a varying rotation to the pulley 112.

The average diameter of the pulley 112 in this instance is about fifty percent greater than the diameter of the driving pulley 113. Accordingly, the average speed of the rotary plate 110 is about two revolutions per second. The frequency deviation produced by the plate 110 varies to a degree depending upon the eccentricity of the pulley 112.

The plate 110 may be used for producing a frequency deviation in one channel, as for example the electrical acoustical channel 11–15–18 of FIG. 1. A second plate 117 may be used for producing a varying frequency change for the electrical acoustical channel 12–19–22 of FIG. 1.

The plate 117 (FIG. 8) is rotated at a varying rate in a similar manner. Thus mounted on the shaft 118 of the plate 117 is an eccentric pulley 119 that is joined to a driving pulley 120 mounted on the shaft 111 of the first plate 110. A flexible belt 121 joins the pulleys 120 and 119. An idler pulley 122, acted upon by a spring 123, maintains suitable belt tension. The driving pulley 120 in this instance has a varying rate of rotation. This fact, combined with the eccentricity of the pulley 119, determines a quite random rate of rotation of the second plate 117. The relative rates of rotation of the plates 110 and 117 thus constantly change. Even with the same average rate of rotation of plates 110 and 117, a sameness in the musical content is avoided. The pattern of differential rotation of the plates 110 and 117 repeats at an exceedingly long interval, which cannot be detected by the ear. Accordingly, a desirable musical effect is achieved.

Additional plates for phase shifting devices or equivalent structure can also be operated in series with the plates 110 and 117. Thus, for example, a driving pulley 124 is illustrated mounted upon the shaft 118 and a fragment of a belt 125 connected thereto.

In FIG. 9 there is illustrated a system essentially similar to that illustrated in FIG. 1, except, in this instance, the organ output is divided into two electrical channels E and O. In the electrical channel E, the even harmonics of all impulses corresponding to notes in the musical range exist, and in the electrical channel O the impulses corresponding to the fundamentals and the odd harmonics exist. This achieves a minimization of beat effects in a manner described in my prior Patent No. 3,041,910, issued July 3, 1962, and entitled "Electrical Circuit Arrangement for Complex Wave Generators." By way of example, if a key corresponding to A_4 (440) is depressed, then electrical impulses at 880, 1760, etc. cycles per second exist in the channel E, whereas impulses of 440, 1320, etc. cycles per second exist in the channel O. When a key corresponding to A (220) is depressed, impulses corresponding to 440, 880, etc. cycles per second exist in the channel E, whereas impulses corresponding to 220, 660, etc. cycles per second exist in the channel O. When a key corresponding to E_5 is depressed, impulses corresponding to 659.26 cycles per second exist in the channel O, and the impulses corresponding to 1318.52 cycles per second exist in the channel E.

Cooperating with the channels E and O are frequency changing devices 15 and 19 which in turn drive the speakers 18 and 22. The channels E and O operate the speakers 13 and 14. The frequency changing devices 15 and 19, as in the form illustrated in FIG. 1, operate with the electrical channels E and O in which the beat effect is minimized and, accordingly, a distinct chorus or celeste effect is perceived.

Of course, if the electronic organ is of a type such as a Hammond tone wheel organ in which beat effects do not occur, the individual frequency changing devices 15 and 19 may directly cooperate with the single output of the organ. Furthermore, frequency changing devices may be used with a single electrical channel to which impulses corresponding to pedal notes are applied, since pedals are depressed one at a time and the possibility of beat effects does not occur because a number of pedal notes are not ordinarily simultaneously sounded.

The inventor claims:

1. In an electrical musical instrument having means for generating electrical impulses containing harmonics and corresponding to notes in a musical range; a first electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯; a second electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B; first means fed by the impulses of said first channel for shifting the frequencies supplied thereto by a predetermined amount and in one directional sense so that the frequencies on a time average basis are changed; a third electrical channel actuated by said first means; second means fed by the impulses of said second channel for shifting the frequencies supplied thereto by a predetermined amount and in one directional sense so that the frequencies on a time average basis are changed; a fourth electrical channel actuated by said second means; first transducer means for the third and fourth channels; and second transducer means directly connected to the first and second channels; independently of said first and second means for shifting frequencies; one of said transducer means having separate components for its respective channels.

2. The combination as set forth in claim 1 in which

said first and second frequency shifting means produce different frequency shifts.

3. In an electrical musical instrument having means for generating electrical impulse containing harmonics and corresponding to notes in a musical range; a first electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯; a second electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B; first means fed by the impulses of said first channel for shifting the frequencies supplied thereto by a predetermined amount and in one directional sense so that the frequencies on a time average basis are changed; a third electrical channel actuated by said first means; second means fed by the impulses of said second channel for shifting the frequencies supplied thereto by a predetermined amount and in one directional sense so that the frequencies on a time average basis are changed; a fourth electrical channel actuated by said second means; and separate transducers for the respective channels, the transducers for said first and second channels being directly connected thereto independently of said first and second means for shifting frequencies.

4. The combination as set forth in claim 2 in which said first and second frequency shifting means produce different frequency shifts.

5. In an electrical musical instrument having means for generating electrical impulses containing harmonics and corresponding to notes in a musical range spanning a plurality of octaves; a first electrical channel deriving from the instrument in accordance with the key thereof those impulses corresponding to C♯, D♯, F, G, A and B in alternate octaves; a second electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B in the other alternate octaves; a third electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in alternate octaves; a fourth electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in the other alternate octaves; separate frequency shifting devices for the channels respectively and each operative to produce predetermined frequency shifts and in one directional sense so that the frequencies on a time average basis are changed; fifth, sixth, seventh and eighth electrical channels actuated by said frequency shifting devices respectively; and a plurality of transducer means for the channels, the transducer means for the first, second, third and fourth electrical channels being directly connected thereto independently of said frequency shifting devices.

6. In an electrical musical instrument having means for generating electrical impulses containing harmonics and corresponding to notes in a musical range spanning a plurality of octaves; a first electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B in alternate octaves; a second electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B in the other alternate octaves; a third electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in alternate octaves; a fourth electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in the other alternate octaves; separate frequency shifting devices of the channels respectively and each operative to produce predetermined frequency shifts and in one directional sense so that the frequencies on a time average basis are changed; fifth, sixth, seventh and eighth electrical channels actuated by said frequency shifting devices respectively; first transducer means for the first, second, third and fourth channels and directly connected thereto independently of said frequency shifting devices; and second transducer means for the fifth, sixth, seventh and eighth channels; one of said transducer means having separate components for its respective channels.

7. The combination as set forth in claim 6 in which said frequency shifting devices produce different frequency shifts.

8. In an electrical musical instrument having means for generating electrical impulses containing harmonics and corresponding to notes in a musical range spanning a plurality of octaves; a first electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B in alternate octaves; a second electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C♯, D♯, F, G, A and B in the other alternate octaves; a third electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in alternate octaves; a fourth electrical channel deriving from the instrument in accordance with the keying thereof those impulses corresponding to C, D, E, F♯, G♯ and A♯ in the other alternate octaves; separate frequency shifting devices for the channels respectively and each operative to produce predetermined frequency shifts and in one directional sense so that the frequencies on a time average basis are changed; fifth, sixth, seventh and eighth electrical channels actuated by said frequency shifting devices respectively; and separate transducer means for the respective channels, the transducer means for the first, second, third and fourth electrical channels being directly connected thereto independently of said frequency shifting devices.

9. The combination as set forth in claim 8 in which said frequency shifting devices produce different frequency shifts.

10. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming a first electrical instrument output for translating impulses corresponding to some of the notes in the range; means forming a second electrical instrument output for translating impulses corresponding to the other notes in the musical range; a first pair of transducers actuated by said outputs; a second pair of transducers actuated by said outputs in such manner as to minimize beat effects; and a pair of frequency shifting devices respectively serially connected to said second pair of transducers for shifting the frequencies applied to said transducers in one directional sense so that the frequencies on a time average basis are changed.

11. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming a first electrical instrument output for translating impulses corresponding to C, D, E, F♯, G♯ and A♯; means forming a second electrical instrument output for translating impulses corresponding to C♯, D♯, F, G, A and B; means forming a pair of electrical channels; means connecting the electrical channels to the outputs to minimize beat effects in the channels; a first pair of transducers; a second pair of transducers; a first pair of electrical connection means respectively between the electrical channels and the first pair of transducers; and a second pair of electrical connection means respectively between the electrical channels and the second pair of transducers, each of said connection means of the second pair including a device for shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

12. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming

a first electrical instrument output for translating impulses corresponding to C, D, E, F♯, G♯ and A♯; means forming a second electrical instrument output for translating impulses corresponding to C♯, D♯, F, G, A and B; means forming a pair of electrical channels; means connecting the electrical channels respectively to the outputs to minimize beat effects in the channels; a first pair of transducers; a second pair of transducers; a first pair of electrical connection means respectively between the electrical channels and the first pair of transducers; and a second pair of electrical connection means respectively between the electrical channels and the second pair of transducers, each of said connection means of the second pair including a device for shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

13. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming a first electrical instrument output for translating impulses corresponding to C, D, E, F♯, G♯ and A♯; means forming a second electrical instrument output for translating impulses corresponding to C♯, D♯, F, G, A and B; means forming a pair of electrical channels; means substantially equally coupling one of the outputs to both of said electrical channels in one fixed relative phase relationship; means substantially equally coupling the other of the outputs to both of said electrical channels in a second different relative fixed phase relationship; a first pair of transducers; a second pair of transducers; a first pair of electrical connection means respectively between the electrical channels and the first pair of transducers; and a second pair of electrical connection means respectively between the electrical channels and the second pair of transducers, each of said connection means of the second pair including a device for shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

14. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming a first electrical instrument output for translating impulses corresponding to some of the notes in the range; means forming a second instrument output for translating impulses corresponding to the other of the notes in the range; means forming a pair of electrical channels; means connecting the electrical channels to the outputs to minimize beat effects in the channels; a first pair of transducers; a second pair of transducers; a first pair of electrical connection means respectively between the electrical channels and the first pair of transducers; and a second pair of electrical connection means respectively between the electrical channels and the second pair of transducers, each of said connection means of the second pair including a device for shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

15. In an electrical musical instrument having means for generating impulses containing harmonics and corresponding to notes in a musical range: means forming a first electrical instrument output for translating impulses corresponding to some of the notes in the range; means forming a second electrical instrument output for translating impulses corresponding to the other notes in the musical range; a pair of electrical channels; transducers respectively operated by the channels; means substantially equally coupling one of the outputs to both of said electrical channels in one fixed phase relationship, and including means for shifting the frequencies of the impulses of said one output in one directional sense so that the frequencies on a time average basis are changed; and means substantially equally coupling the other of the outputs to both of said electrical channels in a second different relative fixed phase relationship, including means for shifting the frequencies of the impulses of said other output in one directional sense so that the frequencies on a time average basis are changed.

16. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; frequency shifting means having an input connected to said instrument output, and having an output connected to said transducer for shifting the frequencies of impulses in one directional sense so that the frequencies on a time average basis are changed; a second transducer connected to said instrument output; and means at least periodically altering the frequency shift produced by said frequency shifting means and independently of the instrument output.

17. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; frequency shifting means having an input connected to said instrument output, and having an output connected to said transducer for shifting the frequencies of impulses in one directional sense so that the frequencies on a time average basis are changed; and means substantially continuously altering the frequency shift produced by said frequency shifting means.

18. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said output to said transducer in serial dependence upon said device; a second transducer connected to said instrument output; and means for moving said rotary part at a random speed within a predetermined range and independently of the instrument output.

19. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said instrument output to said transducer in serial dependence upon said device; a motor; an endless flexible member connecting the motor and the rotary part; and means for altering the effective length of said flexible member between the rotary part and said motor.

20. In an electrical musical instrument having means for generating impulses corersponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said instrument output to said transducer in serial dependence upon said device; a motor; an endless flexible member connecting the motor and the rotary part; and means for randomly altering the effective length of said flexible member between the rotary part and said motor independently of said instrument output, including an irregular cam and a follower engaging the cam and connected to the belt.

21. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said instrument output to said transducer in serial dependence upon said device; a motor; an endless flexible member connecting the motor and the rotary part; and means for altering the effective length of said flexible member between the rotary part and said motor independently of said instrument output, including a continuously rotated crank, and a link connected to the crank and the belt.

22. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said instrument output to said transducer in serial dependence upon said device; an alternating current motor for operating said rotary part; and variable frequency alternating current supply means for operating the motor.

23. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said instrument output to said transducer in serial dependence upon said device; an alternating current motor for operating said rotary part; an alternating current generating means; and means for changing the frequency characteristic of said generating means.

24. In an electrical organ having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said organ output to said transducer in serial dependence upon said device; and alternating current motor for operating said rotary part; an oscillator for driving said motor, said oscillator having an adjustable circuit element for varying the frequency of oscillation; and means operated in accordance with the progress of organ play for adjusting said circuit element.

25. In an electrical organ having means for generating impulses corresponding to notes in a musical range; means forming an instrument output; a transducer; a frequency shifting device having a rotary part for producing a frequency shift directly proportional to the rotational speed of said rotary part; means connecting said organ output to said transducer in serial dependence upon said device; a second transducer connected to said organ output; and means operated in accordance with the progress of organ play for moving said rotary part.

26. In an electrical musical instrument having means for generating impulses corresponding to the components of notes in a musical range: means forming a pair of electrical output channels for the instrument; means for segregating the impulses among the channels to minimize beat effects; and a pair of frequency shifting devices for the channels respectively, each of said devices shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

27. In an electrical musical instrument having means for generating impulses corresponding to the components of notes in a musical range: means forming a pair of electrical output channels for the instrument; means for segregating the impulses among the channels so that the impulses corresponding to the fundamental and odd harmonics for all notes in said range are translated in one channel, and the impulses corresponding to the even harmonics for all notes in said range are translated in the other channel; and a pair of frequency shifting devices for the channels respectively, each of said devices shifting the frequencies of the impulses in one directional sense so that the frequencies on a time average basis are changed.

28. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; rotary frequency shifting means having an electrical input connected to said instrument output, an electrical output connected to said transducer; and a rotary member; and means imparting sustained non-uniform rotation of said rotary member whereby the frequency shift produced by said frequency shifting means is continuously altered.

29. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a transducer; rotary frequency shifting means having an electrical input connected to said instrument output, an electrical output connected to said transducer; and means substantially continuously altering the frequency shift produced by said frequency shifting means comprising a pair of pulleys, one of the pulleys being connected to said rotary member, drive means rotating the other of the pulleys, a flexible belt connecting said pulleys, at least one of said pulleys being eccentrically mounted whereby sustained non-uniform rotation is imparted to said rotary member so that said frequency shifting means produces constantly changing frequency shifts.

30. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a pair of rotary frequency shifting means each interposed in said instrument output to produce frequency shifts in parallel; a number of transmission members for driving the rotary frequency shifting means in serial dependency, said frequency shifting means being operated by different transmission members, one of said transmission members being non-circular whereby each of the frequency shifting means produces a frequency deviation that constantly changes with respect to frequency deviation produced by the other frequency shifting means.

31. In an electrical musical instrument having means for generating impulses corresponding to notes in a musical range: means forming an instrument output; a pair of rotary frequency shifting means each interposed in said instrument output to produce frequency shifts in parallel; a pair of eccentrically mounted pulleys for respectively operating said frequency shifting means; means for driving one of the pulleys; and means operatively connecting the other pulley to said one pulley whereby each of the frequency shifting means produces a frequency deviation that constantly changes with respect to frequency deviation produced by the other frequency shifting means.

32. In an electrical musical instrument for producing chorus effects: means forming an electrical output channel at which there exist impulses in a musical range of at least an octave corresponding to musical notes and their harmonics; first electrical acoustic transducer means connected to said electrical output channel for translating said electrical impulses into sound; a frequency changing device having an electrical input connected to said electrical output channel and having an electrical output; a second electrical acoustic transducer means separate from said first electrical acoustic transducer means, said second electrical transducer means being connected to the electrical output of said frequency changing device for translating said electrical impulses into sound; said frequency changing device having

a plurality of substantially equiangularly spaced plates;
a pickup plate connected to said electrical output;
motive means causing relative unidirectional rotation between the pickup plate and the spaced plates;
circuit means connected to said electrical input for deriving therefrom, progressively phase shifted components of said impulses;
and connection means connected to said circuit means for applying said phase shifted components respectively and successively to said spaced plates whereby the impulses at the electrical input undergo a shift in frequency at the electrical output in one directional sense and to an extent corresponding to the direction and speed of rotation of said motive means.

33. The combination as set forth in claim 32 together with acoustic means for each of said transducers for superimposing vibrato on the radiated sound.

34. The combination as set forth in claim 32 together with means for continuously varying the rate of speed of said motive means.

35. The combination as set forth in claim 32 together with means for operating said motive means at a random speed within a predetermined range.

36. The combination as set forth in claim 32 in which said motive means includes a flexible belt; and means substantially continuously altering the effective length of said flexible belt.

37. The combination as set forth in claim 36 together with an irregular cam and a follower for altering the length of said flexible belt.

38. The combination as set forth in claim 36 together with a continuously rotated crank and a link connected to the crank and said flexible belt.

39. The combination as set forth in claim 36 in which said motive means comprises an induction motor, variable frequency alternating current supply means for operating said motor, and means repeatedly changing the frequency of said supply.

40. The combination as set forth in claim 39 in which said variable frequency alternating current supply means comprises an oscillator, and means operated in accordance with the progress of music for adjusting the frequency of said oscillator.

41. In an electrical musical instrument for producing chorus effects: means forming a pair of electrical output channels at which impulses exist corresponding to musical tones, there being for each electrical output channel,

first electrical acoustic transducer means connected to the corresponding electrical output channel for translating the electrical impulses of said output channel into sound; a frequency changing device having an electrical input connected to said electrical output channel, and having an electrical output; a second electrical acoustic transducer means separate from said first electrical acoustic transducer means, said second electrical transducer means being connected to the output of said frequency changing device for translating into sound the said impulses of said output channel;

the frequency changing device for each electrical output channel including

a plurality of substantially equiangularly spaced plates; a pickup plate connected to the corresponding electrical output; motive means causing relative unidirectional rotation between the pickup plate and the spaced plates; circuit means connected to the corresponding electrical input for deriving therefrom, progressively phase shifted components of said impulses; and connection means connected to said circuit means for applying said phase shifted components respectively and successively to said spaced plates whereby the impulses at the electrical input undergo a shift in frequency at the electrical output in one directional sense and to an extent corresponding to the direction and speed of said motive means;

and means connecting said electrical output channels to an electrical musical instrument whereby said electrical output channels together provide coverage for a common musical range with minimization of beat effects between said electrical output channels.

42. The combination as set forth in claim 41 together with means for operating said motive means at different rates.

43. The combination as set forth in claim 41 together with means for independently and continuously varying the rate of speed of each of said motive means.

44. The combination as set forth in claim 41 together with means for operating the respective motive means at different random speeds within a predetermined range.

45. The combination as set forth in claim 41 in which one of said electrical output channels translates only impulses corresponding to first alternate notes in a musical range, together with their harmonics or partials, and in which the other of said electrical output channels translates only impulses corresponding to the other alternate notes in said musical range, together with their harmonics or partials.

46. The combination as set forth in claim 41 in which one of said electrical output channels translates the fundametals and odd harmonics of notes in a musical range, and the other electrical output channel translates the even harmonics of said notes.

47. The combination as set forth in claim 41 together with a set of musical tone generators for producing impulses corresponding to different notes in a musical range; means substantially equally coupling one of the generators of the set to both of said electrical output channels in one fixed phase relationship; and means substantially equally coupling another generator of the set to both of said channels in a second different fixed phase relationship.

48. The combination as set forth in claim 41 together with a set of musical tone generators for producing impulses corresponding to different notes in a musical range; means substantially equally coupling generators for first alternate notes in said musical range to both of said electrical output channels in one fixed phase relationship; and means substantially equally coupling generators for the other alternate notes to both of said channels in a second different fixed phase relationship.

49. The combination as set forth in claim 48 together with acoustic means for each of said transducers for superimposing vibrato on the radiated sound.

50. The combination as set forth in claim 41 together with a set of musical tone generators for producing impulses corresponding to different notes in a musical range; generators for first alternate notes being connected to one of said electrical output channels, and generators for the other alternate notes being connected to the other of said electrical output channels; means substantially equally coupling the electrical output of one of said frequency changing devices to said second transducers in one fixed phase relationship; and means substantially equally coupling the electrical output of the other of said frequency changing devices to said second transducers in another fixed phase relationship.

51. The combination as set forth in claim 41 together with a number of transmission members for driving said motive means in serial dependency, one of said transmission members being non-circular whereby each of the frequency changing devices produces a frequency deviation that constantly changes with respect to the frequency deviation produced by the other frequency changing device.

52. The combination as set forth in claim 41 together with a flexible endless transmission member connecting said motive means in serial dependency, one of said motive means carrying an eccentric pulley engaging said transmission member whereby each of the frequency changing devices produces a frequency deviation that constantly changes with respect to the frequency deviation produced by the other frequency changing device.

53. The combination as set forth in claim 41 together with acoustic means for each of said transducers for superimposing vibrato on the radiated sound.

References Cited

UNITED STATES PATENTS

2,596,258	5/1952	Leslie	84—1.01
2,899,644	8/1959	Leslie	84—1.25 X
3,160,695	12/1964	Bonham	84—1.25

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