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APPARATUS FOR MINIMIZING BEAT EFFECTS

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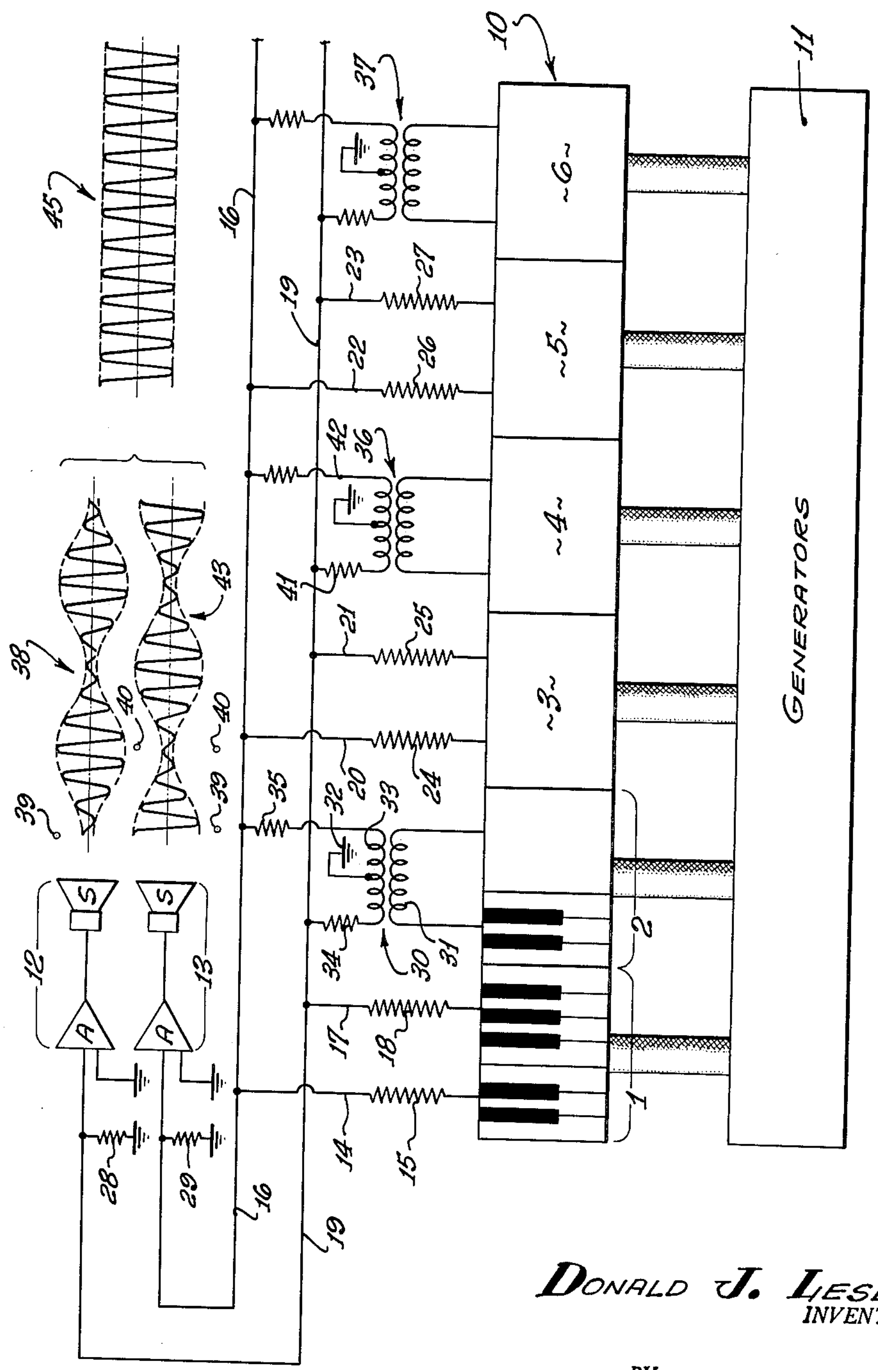

FIG. 1.

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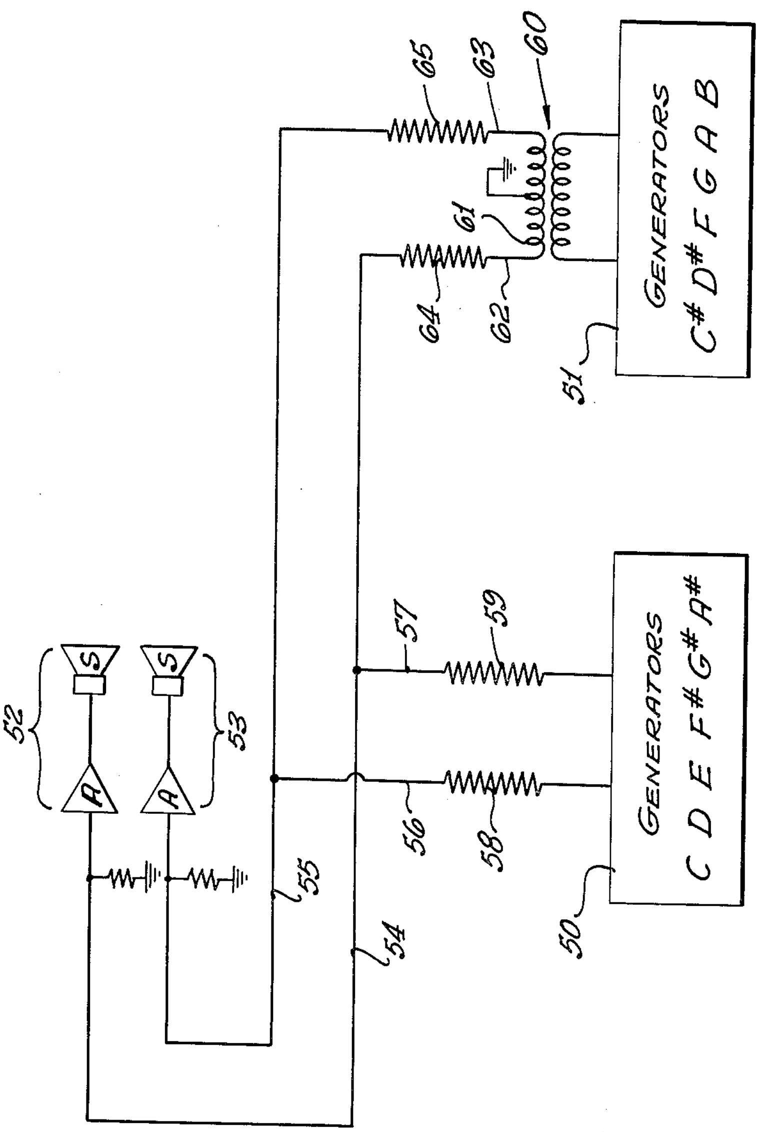
FIG. 2.



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APPARATUS FOR MINIMIZING BEAT EFFECTS

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This invention relates to electronic devices for producing musical tones, such as for an electronic organ.

There are various types of generating systems for electronic organs. Many electronic organs utilize separate or non-locked generators of physical or electrical form for purposes of generating different tones corresponding to the notes in the range of the instrument. Often precise tuning of generators is impossible. Due to slight mistuning, certain "beat effects" may be produced by impulses containing harmonics. For example, in the tempered scale, if A_4 has a frequency of 440 cycles per second, and A_5 due to mistuning has a frequency of 881.5 cycles per second instead of the desired 880 cycles per second, the second harmonic of A_4 will have a frequency differing from the fundamental of A_5 by one and a half cycles per second. The result, if impulses corresponding to these notes are electrically mixed, is an amplitude modulated wave form. A tone of approximately 880 cycles per second will be created, but its amplitude will vary periodically at the rate of one and a half cycles per second. The amplitude variation will be perceived as a "beat." These "beats" or "beat effects" are annoying and especially so to persons musically trained.

"Beat effects" may also be produced for other reasons: for example, due not to mistuning, but to the inherent characteristics of the tempered scale; when impulses, rich in harmonics, corresponding to notes either in fourth or fifth musical interval relationship. For example, it can be shown that in the case of the fifth interval (occurring in all major chords), the third harmonic of one note has a frequency very close to that of the second harmonic of the other note. This is shown in table form below, using as an example the notes A and E as the fundamentals of the tones, and assuming that the key of A above middle C is utilized. However, this condition exists no matter which notes are used to produce the fifth interval.

Note:								
A	Harmonic	1		2	3	4		5
	Frequency	440		880	1,320	1,760		2,200
E	Frequency		659.26		1,318.52		1,977.78	
	Harmonic		1		2		3	

It is to be noted that the adjacent frequencies, corresponding to the second harmonic of the note E and the third harmonic of the note A, are within two cycles of each other.

The fourth intervals, also often used in many chords, produce the same undesirable "beat." In the case of the fourth interval, it is the fourth harmonic of one note that "beats" with the third harmonic of the other, as shown in the table below.

Note:									
A	Harmonic	1		2		3	4	5	
	Frequency	440		880		1,320	1,760	2,200	
D	Frequency		587.33		1,174.66		1,761.99		2,349.32
	Harmonic		1		2		3		4

In this case, also, the "beating" involved is of the order of a few cycles per second. Other intervals also produce "beats," but they are generally less apparent and do not appear to be as undesirable.

The primary object of this invention is to provide a simple arrangement of electrical circuits and electrical-

acoustic channels whereby these "beat effects" are substantially minimized.

Another object of this invention is to provide a novel organization in which two "beat effects" are used to their own mutual destruction. This is done by acoustic interphasing of two sounds, identical except for the fact that their "beats" occur in staggered relationship. Accordingly, maximum and minimum amplitudes from the two acoustic sources complement each other so that the overall sound variation is minimized.

Still another object of this invention is to provide, for the first time, apparatus for minimizing "beat effects" in which all impulses are applied with equal strength to all electrical-acoustic or equivalent channels. Thus, all notes sound alike.

Even where octave mistuning does not exist, impulses in octave relationship may add together electrically in various manners depending upon the fixed phase relationship of the impulses. An electrical addition may take place such that the separate identity of the octave tone is lost or minimized. Other results are also possible. It is accordingly another object of this invention to avoid the consequences of electrical mixture of impulses so that the separate existence of tones is maintained. This is accomplished by phase balancing, that is, by mixing impulses together in two opposite or complementary manners. The result is that the separate existence of tones is preserved and the pipe organ quality for an electronic organ is achieved.

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 a system incorporating the present invention, and wherein beat effects due to octave mistuning are minimized; and

FIG. 2 is a diagrammatic view of another embodiment of the present invention, and wherein beat effects due to fourth and fifth interval notes are minimized.

There is illustrated a keyboard **10** which, by the aid of switches associated with respective keys, controls the operation of corresponding generators indicated by the block **11**.

There are, in this instance, two identical electrical-acoustic channels **12** and **13**, each including an amplifier A and a speaker S.

A plurality of keys or other circuit controllers is shown only diagrammatically by separate successive blocks, designating octaves **1**, **2**, **3**, **4**, **5**, **6**, etc.

Generator circuits for the tones comprising alternate octaves 1, 3, 5, etc. connect to both channels 12 and 13. Thus, a lead 14 extends from all the keys of octave 1 and includes an isolating resistor 15. The lead connects to a bus 16 supplying the amplifier A in the electrical-acoustic channel 13. A connection 17, also including an isolating resistor 18, establishes the connection from the circuits associated with octave 1 to a bus 19 which supplies the amplifier A associated with the other electrical-acoustic channel 12. Similar connections 20, 21, 22 and 23 are provided for the keys of octaves 3 and 5, all including isolating resistors 24, 25, 26 and 27. Terminal grounded resistors 28 and 29, respectively at the inputs of the amplifiers of the electrical-acoustic channels 12 and 13, are of low value relative to the isolating resistors and thereby ensure that the currents from connections 14, 17, 24, 25, 26 and 27 are isolated.

Circuits associated with the other alternate octaves 2, 4, 6, etc. are connected to both electrical-acoustic channels 12 and 13 but in fixed phase spaced relationship to each other, in this instance 180°. Thus, in connection with circuits for the tone generators of octave 2, a transformer 30 is provided that has a primary 31, center-tapped and grounded, as at 32. The secondary 33 is connected at opposite ends to the respective busses 16 and 19 and through isolating resistors 34 and 35. Thus, the impulse corresponding, for example, to C_2 has a maximum positive instantaneous value in the electrical-acoustic channel 12 when that impulse has its maximum negative instantaneous value in the other electrical-acoustic channel 13. Circuits for octaves 4 and 6 are similarly connected, there being provided transformers 36 and 37 together with corresponding connections of the primary and secondary windings of each.

The arrangement illustrated substantially minimizes beat effects due to mistuning of impulses corresponding to notes in octave relationship with each other. The manner in which this is accomplished may be explained by considering any two relatively mistuned notes in octave relationship with respect to each other. The complex impulse corresponding to D_3 exists identically in both channels 12 and 13. The impulse corresponding to D_4 exists in both channels 12 and 13 but in spaced phase relationship, in this instance 180°. The graph 38 plots the amplitude of an impulse having a frequency of approximately 293.66 cycles per second (D_4). The second harmonic of D_3 reaches its maximum positive instantaneous value at the rate of 293.66 per second, if it is precisely tuned. But the fundamental of D_4, due to slight mistuning, may reach its maximum value at a rate of, say, 295 times per second. This means, of course, that the two impulses sometimes reinforce each other and sometimes oppose each other. Hence, the modulated wave form illustrated at 38 results, which is the beat.

At spaced intervals, the instantaneous value of the fundamental of D_4 is most negative when the instantaneous value of the second harmonic of D_3 is most positive. A null point results. One of these is illustrated at the point 39 of graph 38. Peaks, as at 40, occur periodically and at time intervals corresponding to the mistuning.

If at the time 39 the impulse for the fundamental of D_4 is most negative in channel 12, it is most positive in channel 13. This follows since there is a phase displacement between the connections 41 and 42 to the respective channels. But since the second harmonic is still at its maximum positive value in channel 13 whenever it is at maximum positive value in channel 12 (there being no phase displacement between leads 20 and 21), the two signals now add instead of subtract, and a peak is thus created at the time 39. This is illustrated by the wave form 43.

It will be appreciated by similar analysis that the peaks of one wave 38 are interspaced between the peaks of the other wave 43. Both speakers S of the respective electrical-acoustic channels thus create beats but since they are interspaced in time or out of phase, the total effect upon the ears of a listener is a more constant overall amplitude, and as indicated by the wave 45.

The identical considerations prevail no matter which two notes are chosen throughout the range of the instrument and by virtue of the fact that circuits for alternate octaves are connected directly to both channels, whereas the circuits for the other alternate octaves are connected to the respective channels in fixed phase displaced relationship.

Instead of transformers 30, 36 and 37, other phase shifting networks could, of course, be utilized. For example, phase shifting networks in the form of reactive elements can be interposed in leads for circuit groups, or a pair of pickups may be provided at opposite sides of a vibrating reed, or a pair of pickups may be provided in combination with a single tone wheel and so located that they produce out-of-phase components.

The system described is operative even if the phase difference of impulses to the respective channels is more or less than 180°. The system is furthermore operative, more or less, depending upon the relative amplitudes of the second harmonic of one impulse and the fundamental of the impulse an octave above.

In actual use, the speakers of the respective electrical-acoustic channels should be spaced an amount more than half a wave length of the lowest frequency note in the range under consideration. By observing this criterion, adjacent notes will have similar amplitude characteristics and will be relatively unaffected by the phase disparity.

The circuit arrangement disclosed is furthermore useful even if tuning is exact as, for example, in locked octave systems. The use is that the separate identity of tones is preserved. Since impulses are electrically mixed together in opposite or complementary manners, it is ensured that if one manner of mixing tends to suppress any effect due to phasing, the other manner of mixing tends to strengthen it. The result is compensation. For example, if one mode of mixing tends to make an octave tone appear as a mere harmonic partial of another such that its identity is lost, the opposite mixing will necessarily strengthen the separate identity of the octave tone.

In FIG. 2, there is illustrated a system for minimizing beat effects due to fourth and fifth interval notes in the tempered scale.

In this example, there are two groups of generators 50 and 51. Impulses for any two notes either in fourth or fifth musical interval relationship always emanate from the respective generator groups 50 and 51. This is accomplished by including in the group 50 generators for notes in alternate half-tone series, namely, C, D, E, F♯, G♯ and A♯. In the other group 51, generators for notes in the other alternate half-tone series exist, namely, C♯, D♯, F, G, A and B. For example, notes A and E obviously emanate in the groups 51 and 50 respectively, as do any other notes in fifth musical interval relationship. Similarly, the notes A and D exist in the respective groups 51 and 50, as do any other notes in fourth musical interval relationship.

In the present example, there are two electrical-acoustic channels 52 and 53 having input leads 54 and 55. Generators from the group 50 are connected to both input leads 54 and 55 by the aid of connections 56 and 57, both connections including isolating resistors 58 and 59. Generators from the opposite group 51 are connected to the input leads 54 and 55 but in phase-displaced relationship. A transformer 60 is used for this purpose and in a manner similar to that described in the previous form. The secondary winding 61 of the transformer 60 connects at opposite ends respectively to the leads 54 and 55 and by the aid of connections 62 and 63, both including isolating resistors 64 and 65.

Impulses for the notes A and E both exist in the electrical-acoustic channel 52 and by the aid of connections 57 and 62, respectively. A beat effect will be created. In the other electrical-acoustic channel **53**, the impulses for notes A and E likewise exist through connections **56** and **63**, respectively; and a beat effect will also be created. By virtue of the fixed phase displaced relationship for E impulses, the beat effect in one channel will complement the beat effect in the opposite channel to the virtual mutual destruction of both.

The distinct advantage of the systems described is that all impulses exist equally, at least from the quantitative standpoint, in both channels. All notes sound alike, and there are no random changes of points of origin for adjacent notes.

The inventor claims:

1. In an electronic organ system or the like: a set of musical tone generators for producing impulses corresponding to different notes in a musical range; a pair of electrical channels; means substantially equally coupling one of the generators of the set to both channels in one fixed relative phase relationship; and means substantially equally coupling another generator of the set to both of said channels in a second different relative fixed phase relationship; and separate transducer means for the respective channels.

2. The combination as set forth in claim 1 in which the said fixed phase relationships differ from each other by an amount between 90 and 270 electrical degrees.

3. The combination as set forth in claim 1 in which said fixed phase relationships differ from each other by substantially 180 electrical degrees.

4. In an electronic organ system for minimizing electrical mixing effects due to simultaneous operation of generators in octave relationship: a set of generators for producing electrical impulses corresponding to notes in a musical range extending throughout several octaves; a pair of separate electrical channels; separate transducers for the respective channels; connection means for all of the generators to one of said channels; second connection means for generators in alternate octave groups to the other of said channels and in first fixed phase relationship with respect to the connection means therefor to said one channel; and second connection means for generators in the other alternate octave groups to the other of said channels in other fixed phase relationship with respect to the connection means therefor to said one channel.

5. The combination as set forth in claim 4 in which said fixed phase relationships differ from each other by an amount between 90 and 270 electrical degrees.

6. The combination as set forth in claim 4 in which said first fixed phase relationship differs from said other fixed phase relationship by substantially 180 electrical degrees.

7. In an electronic organ system for minimizing beat

effects due to simultaneous operation of mistuned generators in octave relationship: a set of generators for producing electrical impulses corresponding to notes in a musical range extending throughout several octaves; a pair of separate electrical channels; separate transducers for the respective channels; two connections for each generator to the respective channels; and means interposing a fixed phase shift between the connections to the respective channels only for generators in alternate octave groups.

8. The combination as set forth in claim 7 in which said fixed phase shift is substantially 180 electrical degrees.

9. In an electronic organ system for minimizing beat effects due to simultaneous operation of generators in fourth or fifth musical interval relationship: a set of generators for producing electrical impulses corresponding to notes in a musical range; a pair of separate electrical channels; separate transducers for the respective channels; connection means for all of the generators to one of said channels; second connection means for generators in first alternate half-tone relationship to the other of said channels and in fixed phase relationship with respect to the connection means therefor to said one channel; and second connection means for generators in the other alternate half-tone relationship to the other of said channels and in other fixed phase relationship with respect to the connection means therefor to said one channel.

10. The combination as set forth in claim 9 in which said fixed phase relationships differ from each other by an amount between 90 and 270 electrical degrees.

11. The combination as set forth in claim 9 in which said first fixed phase relationship differs from said other fixed phase relationship by substantially 180 electrical degrees.

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