Dec. 1, 1964 D. J. LESLIE 3,159,706

APPARATUS FOR PRODUCING PHASE SHIFT IN ELECTRONIC ORGANS

Filed Aug. 28, 1961 2 Sheets-Sheet 1

FIG. 1.

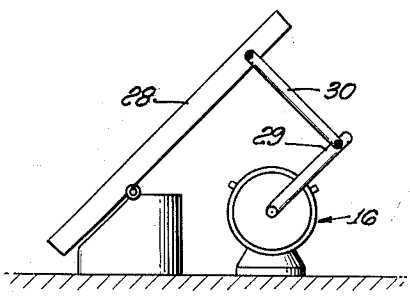


FIG. 2.

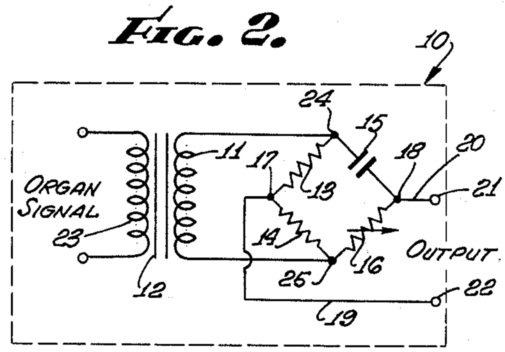


FIG. 3.

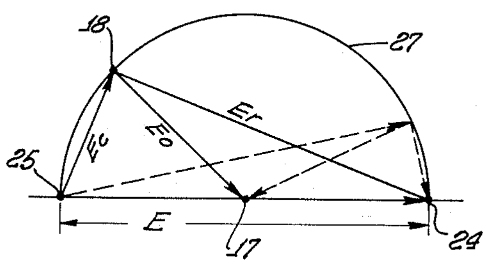


FIG. 4.

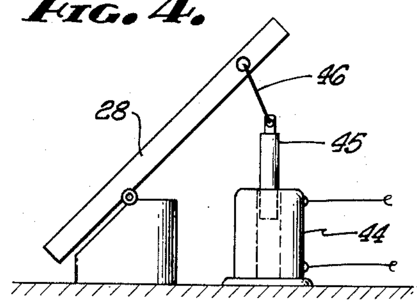


FIG. 5.

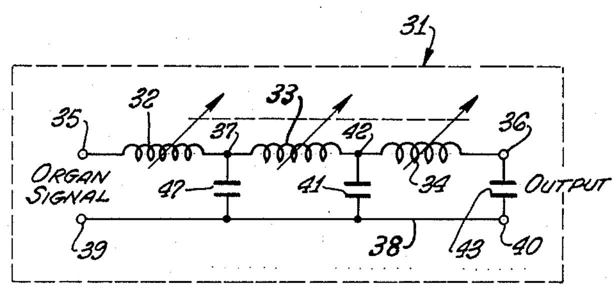
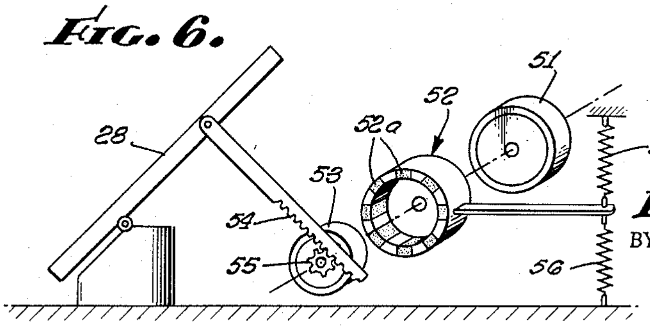


FIG. 6.



INVENTOR.
DONALD J. LESLIE
BY
Flam and Flam
ATTORNEYS.

FIG. 7.

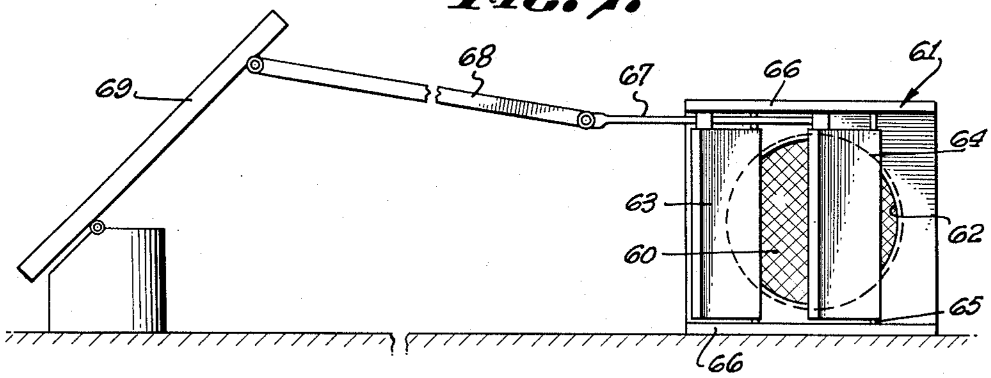


FIG. 8.

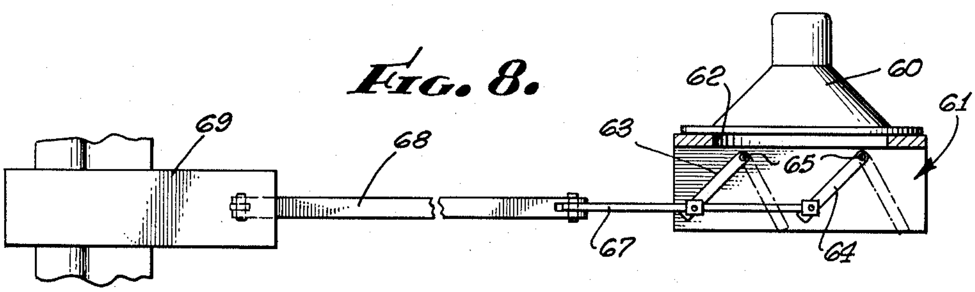
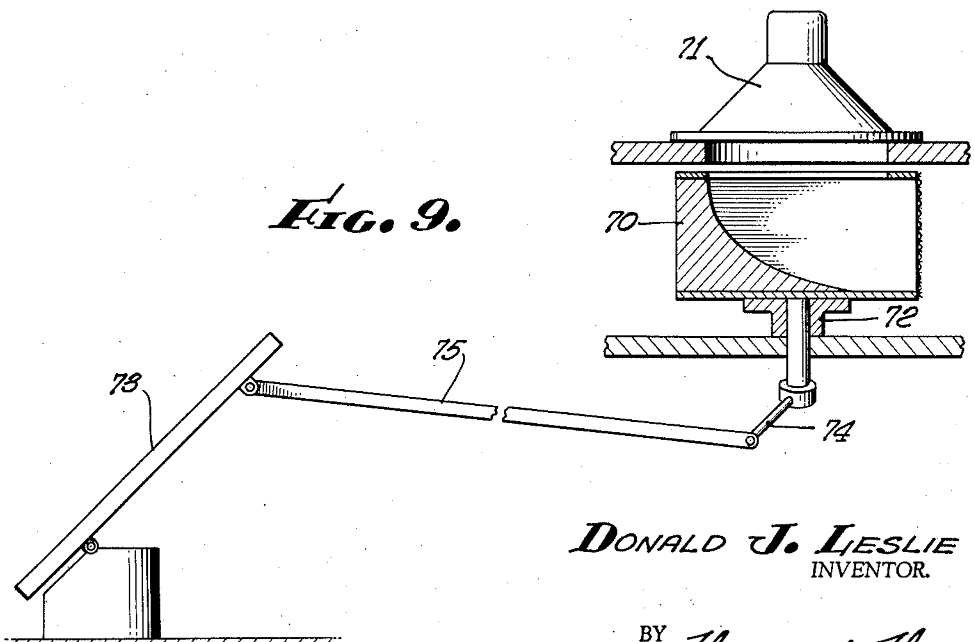


FIG. 9.



DONALD J. LESLIE
INVENTOR.

BY Flam and Flam
ATTORNEYS.

United States Patent Office

3,159,706
Patented Dec. 1, 1964

1

3,159,706
APPARATUS FOR PRODUCING PHASE SHIFT IN ELECTRONIC ORGANS

Donald J. Leslie, % Electric Music, 56 W. Del Mar Blvd., Pasadena, Calif.

Filed Aug. 28, 1961, Ser. No. 134,529
10 Claims. (Cl. 84—1.24)

This invention relates to electronic organs, and particularly to the simulation of effects produced by natural instruments.

Phase shifts are constantly produced by physical movements of musical instruments or accessory apparatus. The human ear cannot sense phase in the absolute sense; but phase changes are sensed; that is, the ear senses the lrst time derivative of phase. Absence of phase shifts results in a certain flatness characteristic of physically fixed sound sources. The phase shifts in natural instruments are not produced in random fashion, but instead in relationship to the progress of the music.

In a pipe organ, the swell shutters not only attenuate sounds emanating from the pipe chambers, but also change the sound radiation pattern, thereby producing the pleasing phase shifts. Phase shifts are constantly produced by the swell shutters since they are almost constantly in motion; the faster the movements of the swell shutters, the greater the effect on the ear of the listener.

An electronic organ speaker is either physically fixed, resulting in no phase shift, or is rotated at a constant speed, resulting in a regular phase shift unrelated to the progress of the music.

An object of this invention is to provide apparatus for introducing phase shifts in an electronic organ which are clearly related to the progress of the music. To accomplish this object, use is made of a phase shift network of suitable design that includes an adjustable or variable element coupled, mechanically or otherwise, to the swell pedal of the electronic organ. Phase shift is then introduced upon movement of the swell pedal, and the action of the swell shutters of a conventional pipe organ is accurately simulated. In other forms of the present invention, use is made of shutters or directional channels operatively associated with a speaker mechanically coupled to the swell pedal.

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 diagrammatically illustrates a side view of a swell pedal of an electronic organ together with a variable resistor forming a part of one embodiment of the present invention;

FIG. 2 is a schematic diagram illustrating how a variable resistor of FIG. 1 is used to effect phase shifting;

FIG. 3 is a phase diagram for the circuit of FIG. 2;

FIG. 4 is a diagrammatic side view similar to FIG. 1 but illustrating a swell pedal cooperating with a variable inductance device that forms a part of the second embodiment of the present invention;

FIG. 5 is a schematic diagram illustrating how the variable inductance device of FIG. 4 is used to accomplish phase shifting;

2

FIG. 6 is a diagrammatic exploded view of a third embodiment of the present invention;

FIG. 7 is a side view with parts removed, diagrammatically illustrating a modified form of the present invention;

FIG. 8 is a top plan view of the apparatus shown in FIG. 7; and

FIG. 9 is a diagrammatic side view with parts removed, illustrating still another modified form of the present invention.

In FIG. 2 there is illustrated a phase shifting device **10** interposed in the circuit for an electric organ signal. The device **10** may be located at any suitable place, as for example at the pre-amplifier stage.

In the present example, the device **10** includes a resistance capacitance bridge excited from the secondary **11** of an iron core transformer **12**. The bridge includes two parallel branches, each connected across the excitation source **11**.

One of the branches comprises two serially connected equal resistors **13** and **14**, and the other branch comprises serially connected capacitor **15** and an adjustable resistor **16**. A mid terminal **17** is formed between resistors **13** and **14**, and a mid terminal **18** is formed between capacitor **15** and resistor **16**. Output leads **19** and **20** extend from mid terminals **17** and **18** respectively to output terminals **21** and **22**. The succeeding stage can thus be connected to the device **10**. The transformer **12** has a primary winding **23** that is driven by the previous stage appropriately to excite the resistance-capacitance bridge.

The manner in which the phase shifting device operates can be understood with reference to the phase diagram, FIG. 3.

The phase diagram is a circle diagram in which the voltage across the input terminals **24** and **25** to the bridge is plotted as the base vector E. The voltage E_c across the capacitor **15** vectorially added to the voltage E_r across the resistor **16** must, of course, equal the base voltage E. Furthermore, these component voltages E_r and E_c must be in 90° relationship with respect to each other. Thus the end of vector E_c, and corresponding to the base of vector E_r must fall along semi-circular arc **27** of which the base voltage E is the diameter. The actual position along the arc depends upon the relative impedance values of the capacitor **15** and resistor **16**.

Thus as the value of the resistor **16** is reduced, the voltage E_c moves into alignment with the base voltage E, as indicated by the dotted line position. As the value of the resistor is increased, E_c diminishes in value, and furthermore approaches a 90° phase relationship with the base voltage E.

The voltage at the output terminals **21** and **22** is the voltage at mid terminal **18** less the voltage at mid terminal **17**. Since resistors **13** and **14** are equal, the voltage of mid terminal **17** is always $E/2$, and thus represented by the mid-point of vector E, which is the center of the circle diagram.

The voltage at mid terminal **18** is represented in the diagram at the juncture of vectors E_c and E_r. The output voltage E_0 is then represented by the vector joining points **18** and **17**. The phase angle of the vector E_0 thus changes from approximately 0° to approximately 180°, the amplitude remaining constant.

In order to adjust the resistor **16**, a coupling is established to the swell pedal, as shown in FIG. 1. For this purpose, the variable resistor **16** is shown as having an operating arm **29** pivotally connected to link **30** which in turn pivotally joins a movable portion of the swell pedal **28**. The swell pedal **28** in any conventional manner is also operatively associated with the circuits of the organ in order to control the amplitude of sound or the intensity of electrical energization of a transducer other than a speaker. As the swell pedal 28 is depressed, in accordance with the progress of the music, the phase angle is accordingly changed.

Since ear senses not phase, but change of phase, it will then be apparent that the perceived effect will depend upon the velocity of movement of the swell pedal 28.

In the form illustrated in FIGS. 4 and 5, a phase shifting network 31 is illustrated that resembles a three-sectioned low pass filter. However, the cutoff frequency is well above the frequency response of the electronic organ. The network comprises three serially connected inductance coils 32, 33 and 34 joining one input terminal 35 to one output terminal 36. Capacitor 47 extends from first inter-coil terminal 37 to a common lead 38 joining the other input and output terminals 39 and 40. A second capacitor 41 is placed between second inter-coil terminal 42 and common lead 38. A third capacitor 43 extends across output terminals 36 and 40.

By following suitable filter design techniques, it is possible, for example, to attain a phase shift the cosine of which is a function of $(1-KLC)$ where K is a frequency related constant, L is the inductance value of the coils and C the capacitance value of capacitors 47, 41 and 43.

Thus by suitably adjusting the inductance values of the series coils 32, 33 and 34, the phase shift may be changed from 0° to 180° corresponding to a change in the cosine function $(1-KLC)$ from $+1$ to -1.

In order to change the value of the inductances 32, 33 and 34, the coils are wound upon a common frame 44 with respect to which an element 45 of magnetic material is movable. In the present example, the element 45 comprises a powdered iron core, and it is pivotally connected by a link 46 to the swell pedal 28.

Upon movement of the swell pedal 28, the phase shift produced by the device 31 is varied substantially between 0° and 180°.

By observing suitable design techniques, attenuation can be constant and independent of frequency throughout the pass band. However, in this instance as in the previous form, the phase shift is a function of frequency.

In the form of the invention illustrated in FIG. 6, a variable circuit element 51 is provided that is connected to a rotary magnet unit 52. The variable circuit element 51 may correspond to the adjustable resistor 16 or the adjustable impedance coils 32, 33 and 34 of the forms previously described. The magnet unit 52 has a series of equiangularly disposed permanent magnets 52*a*, in this instance, eight in number carried upon a common support.

The magnets have poles facing inwardly toward the axis of unit 52, and spaced uniformly therefrom. The polarity of the magnets alternates. Cooperable with the magnets is an armature or drum 53 of magnetic material. This drum is mounted for rotation about the axis of the unit 52, and the drum completes flux paths between the magnets whereby a coupling is established. The swell pedal 28 imparts motion to the drum by the aid of a rack 54 pivotally connected thereto which engages a small pinion 55 connected to the drum 53. The arrangement is thus one of an eddy current brake or clutch, the coupling being established by magnetic drag. The rack and pinion arrangement causes the drum to rotate throughout several revolutions upon full depression of the pedal 28.

The magnet device 52 is biased to a central neutral position by the aid of a spring 56. When the swell pedal 28 is moved, a substantial dragging force is imposed on the magnetic device 52, thereby changing the value of the impedance element 51. The motion of the pedal 28 is thus amplified so that a slight, but rapid movement of the pedal 28 causes movement of the circuit element 51 to its extreme position, where it stays until the pedal 28 decelerates or reverses. A 180° shift then does not depend upon the pedal 28 being depressed to the floor. If the swell pedal is slowly moved, a slight phase shift will be produced since the spring 56 checks the motion.

Thus, in the present example, changes in phase are produced not in response to velocity of the swell pedal 28, but instead in response to its acceleration. Since sudden changes in the swell pedal 28 coincide with changes in the music, the phase shift introduced correlates with only pronounced changes in the progress of the music.

In the form illustrated in FIGS. 7 and 8, a speaker 60 is mounted upon a frame 61. The speaker cone registers with an opening 62 provided by frame 61.

In front of the opening 62 are a pair of shutters 63 and 64 pivotally mounted about parallel axes extending parallel to the plane of the opening 62. For this purpose, pivot pins 65 projecting from the rear corners of the shutters 63 and 64 are journalled in top and bottom flanges 66 in the frame 61.

The shutters 63 and 64 are moved in unison and maintained in parallel relationship by the aid of pivotally connected linkage parts 67 and 68 pivotally joined to the swell pedal 69. The shutters channel the sound primarily by reflection. A change in the length of the sound path in reaching the ear of the listener due to a change in the shutter position accomplishes a change in phase. The linkage 67, 68 is so designed and the shutters are so spaced that the shutters do not significantly attenuate the sound. The shutters are preferably limited to approximately a 45° movement on opposite sides of the center, and as indicated by the full and phantom lines in FIG. 8.

The linkage 67, 68 causes the shutters to shift as the swell pedal is moved, imparting a characteristic phase shift to the music.

In the form illustrated in FIG. 9, a directional sound channel 70 registers with a speaker 71, and is supported, as by a bearing 72, for angular reciprocation. The sound channel is connected to the swell pedal 73 by a crank 74 and rod 75. As the swell pedal 73 is moved, the angular orientation of the directional sound channel shifts angularly and a result similar to that produced by the shutters of the previous form is obtained.

The inventor claims:

1. In an electronic organ: an organ signal circuit; a phase shifting device interposed in said circuit, and including an element operative to adjust the phase shift produced by said device; a swell pedal; and coupling means between the swell pedal and said element.

2. The combination as set forth in claim 1 in which said coupling is magnetic.

3. In an electronic organ: an organ signal circuit; a phase shifting network interposed in said circuit including a circuit element having a variable impedance operative to change the phase shift produced by said device; said variable impedance having movable actuator means for mechanical adjustment thereof; a swell pedal; and a coupling between said swell pedal and said actuator.

4. The combination as set forth in claim 3 together with biasing means for determining a normal position of said actuator, and in which said coupling comprises magnetic drag members respectively connected to the swell pedal and the actuator.

5. The combination as set forth in claim 3 in which said actuator is biased to a normal position and in which said coupling is provided by a pair of relatively removable magnetic members respectively connected to the swell pedal and the actuator, one of said members having magnet means providing a series of spaced magnet poles, and the other of said members comprising an armature of magnetic material movable relative to said magnets.

6. In an electronic organ: an organ signal circuit; an adjustable phase shifting device interposed in said circuit; a swell pedal; and coupling means between the pedal and the device for adjusting said device to change the phase at a rate corresponding to the velocity of motion of said pedal.

7. In an electronic organ: an organ signal circuit; an adjustable phase shifting device interposed in said circuit;

a swell pedal; and coupling means between the pedal and the device for adjusting said device to change the phase at a rate corresponding to the acceleration of motion of said pedal.

8. The combination as set forth in claim 7 together with means for limiting the change in phase of said device.

9. In an electronic organ: a speaker; acoustic sound channeling means registering with the speaker; means pivotally mounting said sound channeling means for angular reciprocation; a swell pedal; and a linkage between said sound channeling means and said swell pedal; said sound channeling means having a sound attenuating characteristic substantially independent of its permitted positions.

10. In an electronic organ: an electrical-acoustic transducer; a swell pedal operatively associated with the transducer for controlling the intensity of electrical energization of said transducer; means movable for shifting the phase of the transducer signals; and a linkage between the swell pedal and said movable means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,114,680	Goldsmith	Apr. 19, 1938
2,468,062	Hanert	Apr. 26, 1949
2,509,923	Hanert	May 30, 1950
2,755,695	Krauss et al.	July 24, 1956
2,986,953	De Armond et al.	June 6, 1961
2,995,054	Leslie	Aug. 8, 1961
3,004,459	Jones	Oct. 17, 1961