# United States Patent

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[54] **ELECTRONIC MUSICAL INSTRUMENT WITH PHASE SHIFT VIBRATO**
**14 Claims, 5 Drawing Figs.**

[52] **U.S. Cl.** .......... **84/1.25,** 84/1.18, 84/DIG. 19
[51] **Int. Cl.** .......... **G10h 1/02**
[50] **Field of Search** .......... 84/1.01, 1.18, 1.24, 1.25

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**ABSTRACT:** Organ or the like electronic musical instrument tones are subjected to a phase-shift vibrato utilizing a plurality of series connected stages of phase shifting, each stage comprising a capacitor and a light-dependent resistor respectively connected to the collector and emitter of a transistor. The resistance of the light-dependent resistor is varied by a lamp excited at a vibrato frequency. Different frequency bands are connected to individual stages such that the higher the frequency range of the band the larger the number of stages the band is passed through.

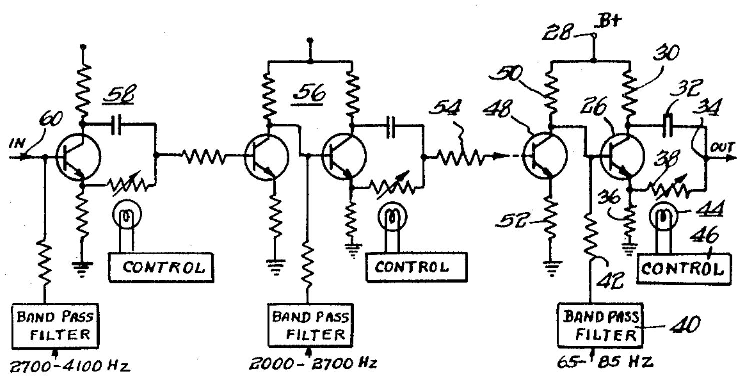


Fig. 1.

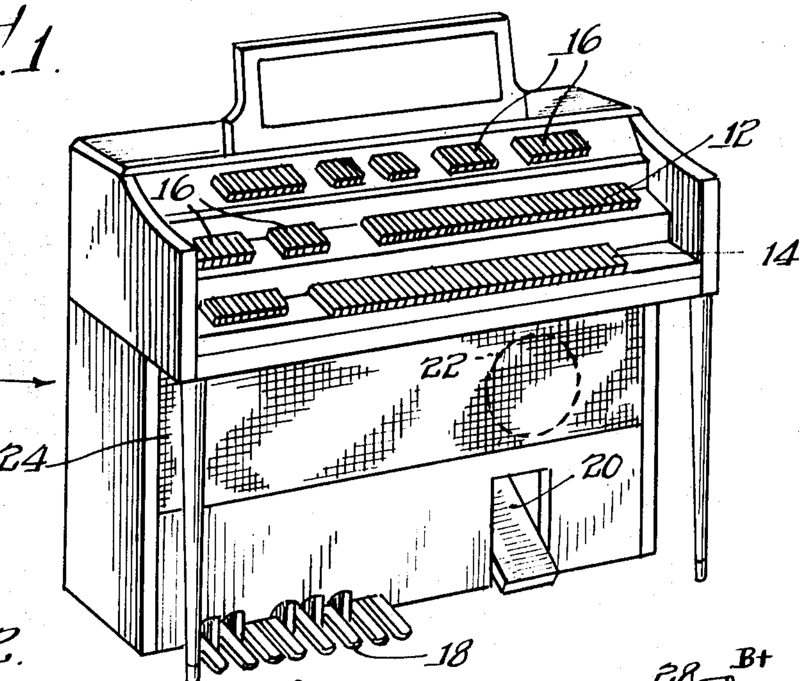



Fig. 2.

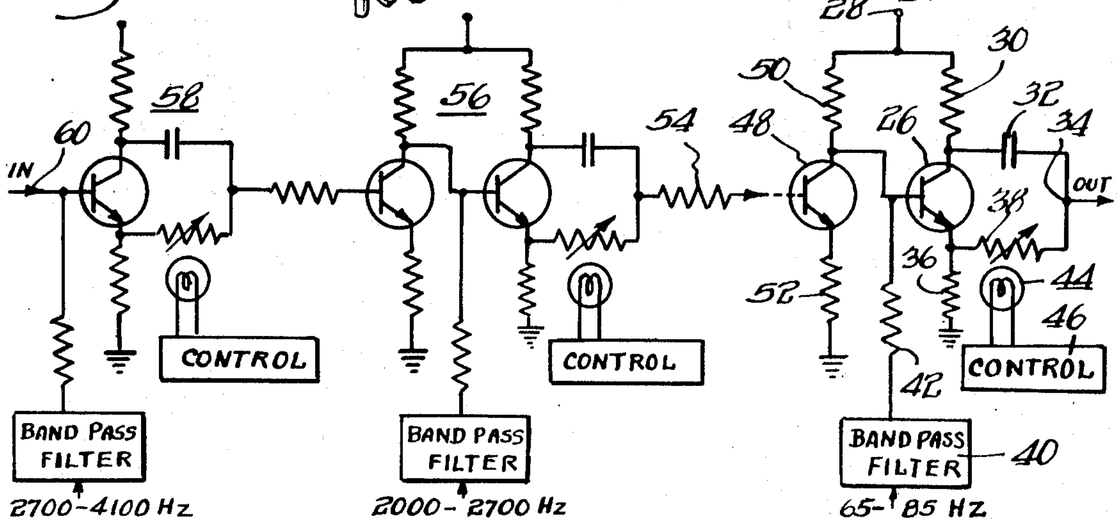



Fig. 3.

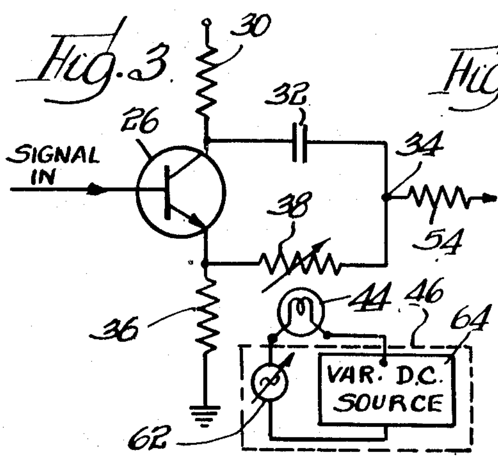



Fig. 4.

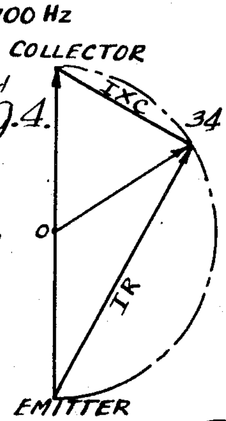
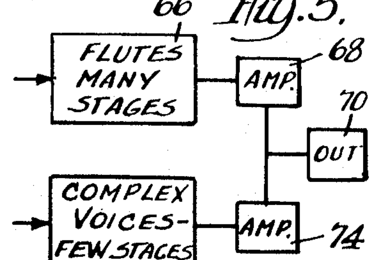



Fig. 5.

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## ELECTRONIC MUSICAL INSTRUMENT WITH PHASE SHIFT VIBRATO

### BACKGROUND OF THE INVENTION

It is well recognized that types of music sound significantly better when played with a vibrato, i.e., a pitch variation. A tone of constant pitch tends to become somewhat boring in time, and the pitch fluctuation renders the music more pleasant and palatable. Various efforts have been made in the past to produce vibrato or pitch fluctuation in electronic musical instruments. Efforts to attain this end electronically have either not been successful, or have been too expensive.

Satisfactory vibrato has been obtained by the use of movable speakers or horns, whereby the apparent source of this sound is swung around, and thus approaches and recedes from the listener, providing a Doppler-effect vibrato which is quite pleasing. However, such systems have necessarily been, at least in part, mechanical. Thus, there have been problems of mechanical noise and wear, as well as the necessity of providing substantial physical space for the rotating apparatus. Cost has tended to be high.

If further is recognized that pitch fluctuations are not particularly effective at low frequencies. However, tremolo or amplitude modulation is quite effective at low speeds. Systems have been developed using a Doppler-effect vibrato for the higher pitch musical tones, and using amplitude modulation to produce a tremolo at a lower audio frequency. Obviously, this has increased the cost over and beyond that of producing simply a phase shift vibrato.

### SUMMARY OF THE DISCLOSURE

In accordance with the present invention, it is proposed to provide a phase-shift vibrato in which a phase shifter comprises a resistance-capacitance network wherein the resistance comprises a light-dependent resistor (LDR). A light adjacent the LDR is varied at a vibrato frequency, i.e., 5 to 8 cycles per second, whereby the resistance of the LDR varies from nearly zero to a very high resistance, and thereby shifting the phase and hence, the frequency of musical tones applied to the phase shifter. In particular, the tibia and flute tones, i.e., rather simple tones, are filtered in one-half to one octave groupings, and the outputs of various groupings are diversely applied to one or more stages of phase shifters. In particular, relatively low frequency tones are applied to one phase-shifting stage, while the next group is applied to two stages of phase shifting, etc. whereby the highest frequency grouping may be applied to nine or 10 stages (or possibly more) or phase shifting. Thus, a substantially uniform percentage of phase shift is obtained throughout the gamut of tones of the organ.

In the particular phase shifter used, the effect of the capacitor is relatively constant over most of the frequency range, but the impedance thereof rises quite rapidly in the lower frequency range, thereby producing amplitude modulation which is more effective in such frequency range.

It also has been found that the relatively simple tones, i.e., tibias and flutes, sound best with a fairly large degree of vibrato. However, the more complex voices, such as brass, reed, and string do not respond so well to large amounts of vibrato. Hence, in accordance with the present invention, many stages of phase shifting are provided for the flute and tibia tones, but only a few for the complex voices.

As further features of the invention, individual control is provided for the lamps of the various phase-shifting stages, both as to phase and frequency of the various stages for the provision of novel vibrato effects, and also as to amplitude of change of control degree of frequency modulation of different frequencies.

### DETAILED DISCLOSURE

The present invention will be understood in all of its ramifications with reference to the accompanying drawings wherein:

FIG. 1 is a perspective view of an organ constructed in accordance with the present invention;

FIG. 2 is a schematic wiring diagram illustrating the principles of the present invention;

FIG. 3 is a schematic wiring diagram showing a single stage of phase shifting illustrating various types of control on the lamp for the LDR;

FIG. 4 is a vector diagram illustrating the phase relationships involved; and

FIG. 5 is a fragmentary block diagram illustrating the relationship of the flute and the complete voices as the vibrato is applied thereto.

Turning first of FIG. 1, there will be seen an electronic organ **10** of the so-called spinet type having two shortened and overlapping keyboards or manuals **12** and **14** with a plurality of stop tablets or controls **16** mounted in proximity thereto. The organ is also provided with a pedal board or clavier **18** and a sweel pedal **20** for controlling the overall volume of the instrument. One or more loudspeakers **22** are mounted behind grille cloth **24** on the front of the instrument below the keyboard. The organ is also provided with suitable tone generators and amplifiers (not shown) which may be of known design.

Turning now to FIG. 2 and first to the right end thereof, there will be seen an NPN transistor **26** receiving B+ potential from a source **28** through a resistor **30** leading to the collector. A capacitor **32** is connected to the collector and to an output point **34**.

The emitter is connected to ground through a resistor **36** equal to the resistor **30**, and the emitter is also connected through a resistor **38** to the output point **34**. The resistor **38** is illustrated as being a variable resistor and is, infact, a light-dependent resistor, otherwise known as an LDR.

The flute tones are applied to a band pass filter **40** which passes tones from approximately 65 to 87 Hertz, the output of the filter being connected through a resistor **42** to the base of the transistor **26**. Alternative to applying all of the flute tones to the filter **40**, the generators (not shown) of flute tones in this frequency range could be connected together and isolated from the remaining flute tones.

A lamp **44** is disposed adjacent the LDR **38** so that the light from the lamp falls on the LDR. A control unit **46** is connected to the lamp **44**, and in the simplest case comprises an oscillator providing subaudio frequencies on the order of 5 to 8 cycles per second.

Since the resistors **30** and **36** are of equal value, the collector and emitter of transistor **26** will have output potentials thereon approximately equal in magnitude and 180° out of phase. When the lamp **44** is dark, the LDR **38** will have a very resistance, whereby practically all of the signal will be supplied through the capacitor **32**, the output at **34** thereby being of substantially the same phase as the collector. Conversely, when the lamp **44** is at full brilliance, the LDR **38** will be very nearly zero resistance, and the phase of the output signal at **34** will be substantially the same as that of the emitter.

The phase relationship will be seen in the vector diagram of FIG. 4. As will be apparent, the phase and amplitude of the output at the collector is of a predetermined magnitude straight up, while the phase and magnitude of the output at the emitter is of the same magnitude, and straight down. Within practical limits, the maximum resistance of the LDR is greater than 1 megohm, while the minimum resistance is on the order of 200 ohms. Since these are finite values, the output phase at **34** can never be quite the same as either that of the collector or emitter, although it will approach that of the collector and emitter to an extent that there is an overall phase change of approximately 160°. As will be apparent in the vector diagram, the position of the resultant vector at **34** is determined by the relative values of the current through the capacitor times the capacitive reactance thereof, and the current through the LDR times the resistance thereof.

Returning to FIG. 2, the phase shifter including the transistor **26** will be understood as being but the last of a series of phase shifters. A buffer amplifier stage including a transistor **48** has the output thereof taken from the collector connected to the base of the transistor **26**. Positive potential is supplied to the collector through a resistor **50** from the source **28** while the emitter is grounded through a resistor **52**.

Signals to the base of the transistor **48** are supplied from preceding stages, not all of which are shown herein, isolating resistors **54** being provided from one stage to the next. One stage **56** comprising a buffer amplifier and transistor, similar to those previously described, handles the frequency range of 2,000 to 2,700 Hertz, while another stage **58** omits the buffer amplifier, and handles the frequency band from 2,700 to 4,100 Hertz. The leftmost stage, omitting the buffer amplifier, may be considered as the first stage, whereby it does not require the buffer amplifier. However, it may be provided with an input at **60**.

In accordance with the preceding description, the amount of frequency deviation is directly proportional to frequency. Thus, if the organ may be considered as having 2 vibrato depth, which has been found to be desirable, a note of 440 Hertz will be shifting ±8.8 Hertz or from 448.8 to 431.2 Hertz.

The number of stages of phase shifters required to obtain the desired ±2 percent frequency modulation is calculated as follows:

Assume maximum phase shift, $\Phi\Delta$, to be 160°=2.8 radians

Required frequency deviation, $\Delta f$, to be ±2 percent $f$

Modulating frequency, $fm$ to be 6 Hertz

$\Delta f = \Phi\Delta \cdot fm$

To calculate the highest frequency which can be frequency modulated at ±2 percent by using only one stage of phase shift:

$\Delta f = 2.8$ radian ·6 Hertz

$\Delta f = 16.8$ Hertz

Therefore, if 16.8 Hertz frequency deviation can be obtained from one stage, the highest frequency is determined by ±2 percent = 4 percent total.

16.8 Hertz = $0.04f$

420 Hertz = $f$

2 stages = $2f$=840 Hertz

4 stages = $4f$=1,680 Hertz

8 stages = $8f$=3,360 Hertz

10 stages = $10f$=4,200 Hertz

10 **stages in cascade should produce a phase shift of** 1,600° or 28 radians.

Reference now should be had to FIG. 3, wherein one of the phase-shifting stages is shown, the same numerals again being used to avoid repetition and prolixity. The difference is that the component parts of a satisfactory control unit **46** are shown therein, as including a variable signal source or generator **62** and a variable DC source **64**, the combination being in series with the lamp **44**.

We have discovered that the maximum phase shift does not occur within the same voltage swing for all frequencies. For example, frequencies below 1,000 Hertz experience their maximum phase shift from zero to one-third lamp voltage. The lower the frequency, the less change in lamp voltage is required to produce the maximum phase shift. (Below about 250 Hertz the reactance of the capacitor **32** rises and the phase shift becomes overshadowed by amplitude modulation which increases as the frequency decreases.) Frequencies in the range of 800 to 1,600 Hertz experience their maximum phase shift within one-third to two-thirds of lamp voltage. Higher frequencies have their maximum phase shift from two-thirds to maximum lamp voltage. It follows that the amount of frequency modulation of mid-to-low frequencies can be controlled by the amount of DC current the modulating current for the LDR lamps is mixed with, and this is the purpose of the variable DC source **64**.

Further, complexities in vibrato are effected by the variable vibrato generator **62**. For utmost variation, there is a separate generator **62** for each control unit, and each is variable in amplitude and also phase and/or frequency.

With reference to FIG. **5**, it will be seen that the flute tones or other relatively simple tones are applied to many stages of phase shift as indicated at **66**, the output thereof being connected to an amplifier **68** and onto an output circuit which may comprise a power amplifier and loudspeaker, indicated at **70**. Conversely, the complex voices are applied at **72** to only a few stages of phase-shift vibrato, on the order of two or three stages, the output thereof being applied to an amplifier at **74** and the output thereof again being taken at **70**.

From the foregoing it will be apparent that we have provided a new vibrato arrangement in electronic organs or the like which provides for a uniform vibrato across the frequency gamut of the instrument, and with inherent amplitude modulation for the lowest tones. Variation in amplitude, phase, and frequency of the vibrato generator on each stage provides for interesting and realistic vibrato, contrary to the usual locked electronic organ vibrato, while variation of the DC source in series with the exciter lamp of the LDR provides for further variation by controlling the vibrato as applied to different frequency bands.

The specific example of the invention as herein shown and described is for illustrative purposes. Various changes in structure will no doubt occur to those skilled in the art and will be understood as forming a part of the present invention insofar as they fall within the spirit and scope of the appended claims.

The invention is claimed as follows:

1. In an electronic musical instrument comprising means connected to tone generating means and providing frequency bands of electric oscillations corresponding to various musical tones, a plurality of phase-shifting means, means connecting said phase-shifting means in series with one another, output means connected to the last of said phase-shifting means, and means connecting each of said frequency band providing means to said phase-shifting means, the lowest frequency band being connected to the phase-shiftinng means nearest the output and subsequent bands being connected to phase-shifting means means successively farther from the output whereby higher frequency bands are subjected to further stages of phase shifting, whereby to produce a vibrato to musical tones, each of said phase-shifting means including means for providing two electric oscillations corresponding to said musical tones with a substantially 180° phase relation, resistance and reactance means serially connected across said **180°** phase relation providing means, there being an output between said resistance means and said reactance means, said resistance means comprising a light-dependent resistor, a lamp in close optical proximity to said light-dependent resistor, and means for energizing said lamp at a vibrato frequency to change the resistance of said light-dependent resistor and thereby to frequency modulate the musical tones to produce a vibrato.

2. An electronic musical instrument as set forth in claim **1** wherein there are two series of phase-shifting means, one of said series comprising many stages and having relatively simple tone oscillations connected thereto, the other having relatively few stages having complex tone oscillations connected thereto.

3. An electronic musical instrument as set forth in claim **1** and further including means providing a DC potential in series with at least some of said lamps.

4. An electronic musical instrument as set forth in claim **3** wherein the DC potential providing means includes means for providing different DC potentials to different lamps.

5. An electronic musical instrument as set forth in claim **4** wherein higher DC potentials are provided in series with lamps corresponding to high frequency tone oscillations and lower DC potentials are provided in series with lamps corresponding to lower frequency tone oscillations.

6. An electronic musical instrument as set forth in claim **3** and further including means for adjusting the DC potential.

7. An electronic musical instrument as set forth in claim **1** wherein the vibrato frequency comprises alternating current potential, the alternating current potential applied to at least one of said lamps being different from that applied to at least one other of said lamps.

8. An electronic musical instrument as set forth in claim **7** wherein the difference is as to at least one of the parameters of amplitude, frequency, and phase.

9. An electronic musical instrument as set forth in claim 7 and further including means for adjusting the AC potential.

10. An electronic musical instrument as set forth in claim 9 wherein the adjustment of AC potential is to at least one of the parameters of amplitude, frequency and phase.

11. An electronic musical instrument as set forth in claim 7 and further including means providing a DC potential in series with at least some of said lamps.

12. An electronic musical instrument as set forth in claim 11, wherein different DC potentials are applied to different lamps.

13. In an electronic musical instrument comprising means connected to tone generating means and providing frequency bands of electric oscillations corresponding to various musical tones, a plurality of phase-shifting means, means connecting said phase-shifting means in series with another, output means connected to the last of said phase-shifting and means connecting each of said frequency band proving means to said phase-shifting means, the lowest frequency band being connected to the phase-shifting means nearest the output and subsequent bands being connected to phase-shifting means successively farther from the output whereby higher frequency bands are subjected to further stages of phase shifting, whereby to produce a vibrato in musical tones, each of said phase-shifting means including means for providing two electric oscillations corresponding to said musical tones with a substantially 180° phase relation, resistance and reactance means serially connected across said 180° phase relation providing means, there being an output between said resistance means and said reactance means, one of said resistance means and said reactance means being variable, and means for varying said one means at a vibrato frequency to frequency modulate the musical tones to produce a vibrato.

14. An electronic musical instrument as set forth in claim 13 wherein there are two series of phase-shifting means, one of said series comprising many stages and having relatively simple tone oscillations connected thereto, the other having relatively few stages and having complex tone oscillations connected thereto.