Aug. 20, 1968 D. M. PARK 3,398,230

SEQUENTIAL CONNECTION OF SPEAKERS FOR MOVING SOUND SOURCE SIMULATION OR THE LIKE

Filed Jan. 13, 1965 3 Sheets-Sheet 1

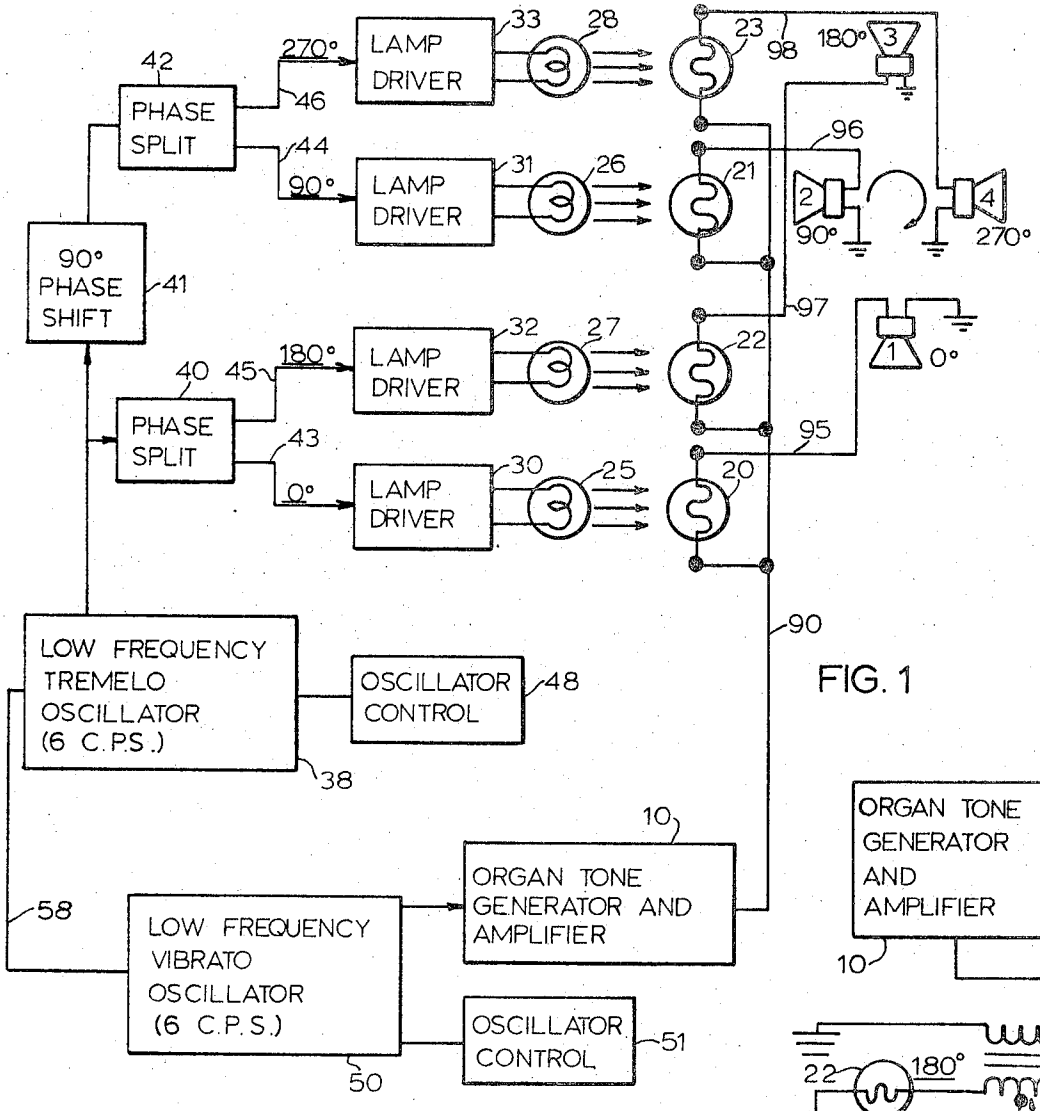


FIG. 1

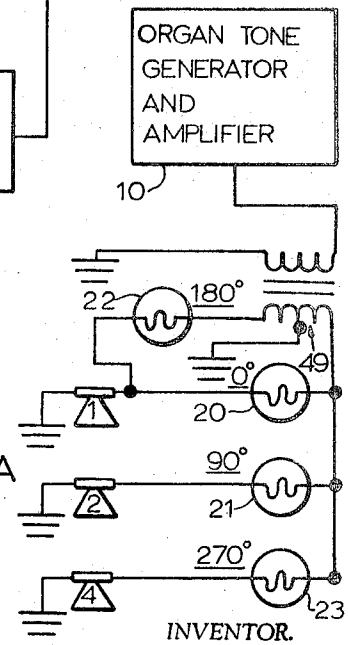


FIG. 4 A

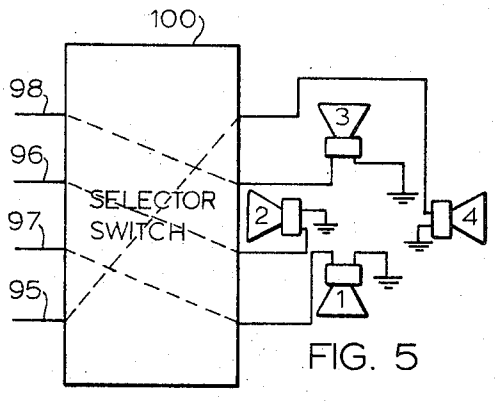


FIG. 5

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SEQUENTIAL CONNECTION OF SPEAKERS FOR MOVING SOUND SOURCE SIMULATION OR THE LIKE

Filed Jan. 13, 1965 3 Sheets-Sheet 2

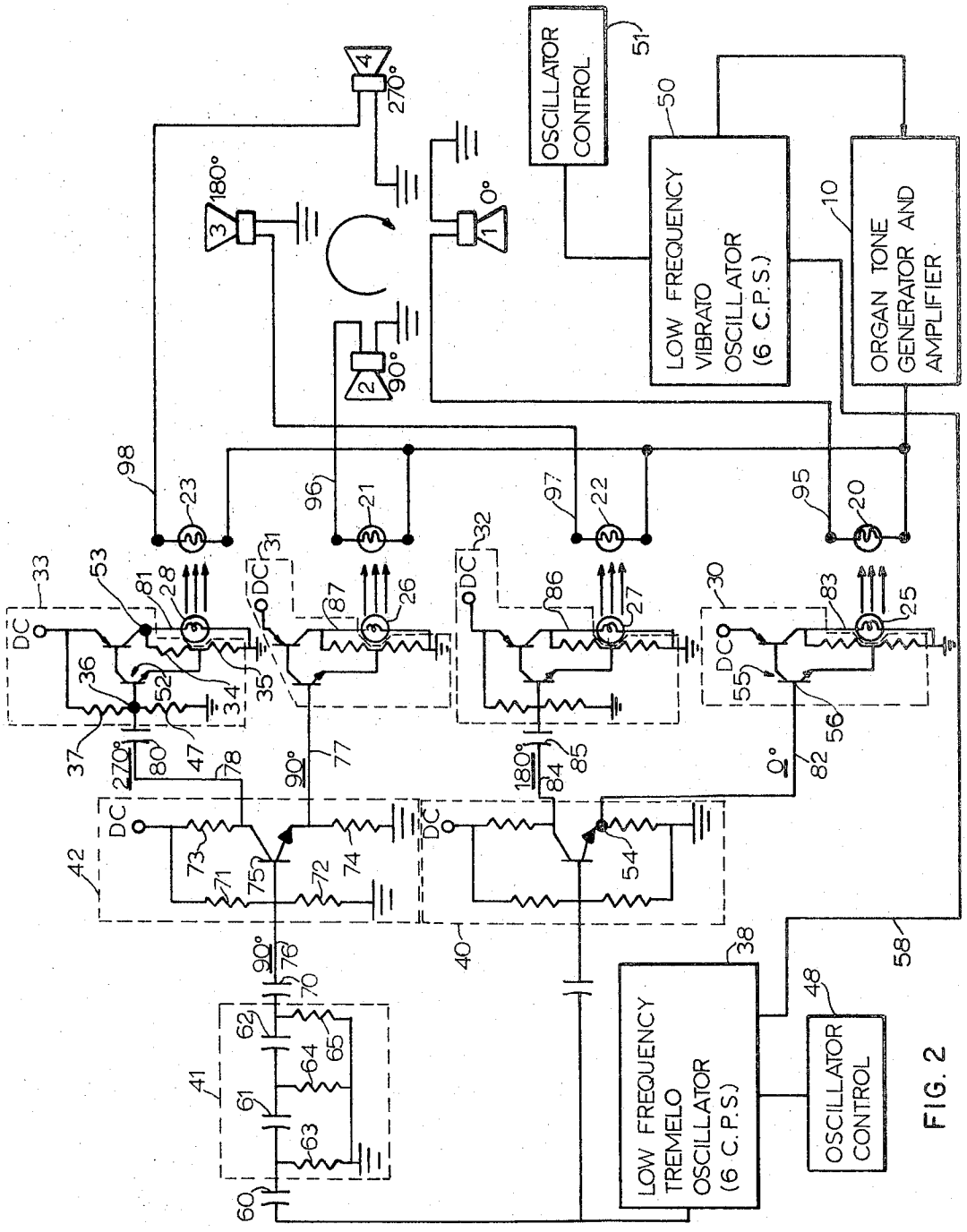


FIG. 2

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SEQUENTIAL CONNECTION OF SPEAKERS FOR MOVING SOUND SOURCE SIMULATION OR THE LIKE
Filed Jan. 13, 1965 3 Sheets-Sheet 3

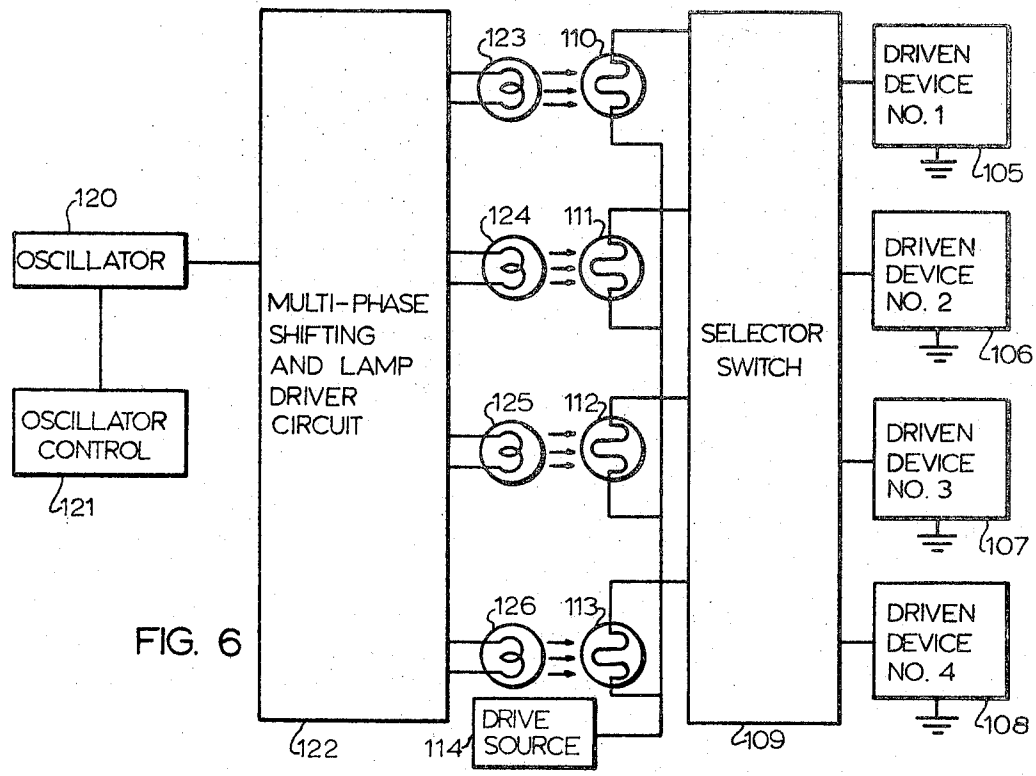


FIG. 6

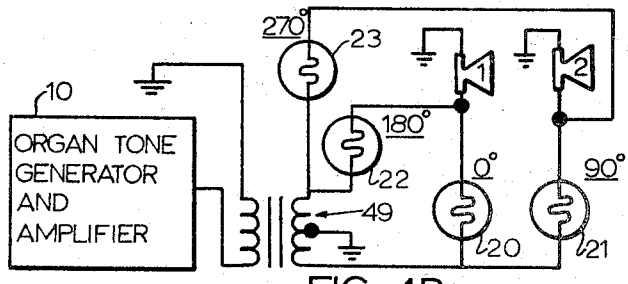


FIG. 4B

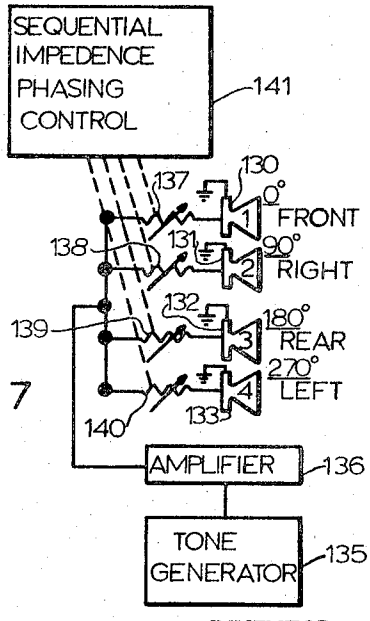


FIG. 7

FIG. 3

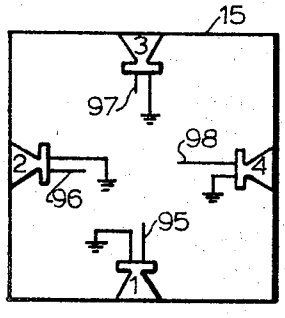
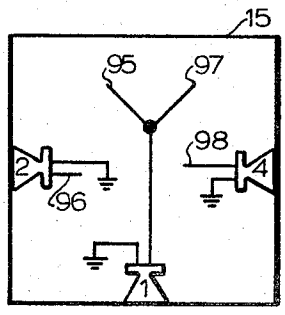


FIG. 4



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3,398,230

SEQUENTIAL CONNECTION OF SPEAKERS FOR MOVING SOUND SOURCE SIMULATION OR THE LIKE

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7 Claims. (Cl. 84—1.18)

ABSTRACT OF THE DISCLOSURE

A plurality of speakers simulate a moving sound source by means of light sensitive impedances connected in series with each speaker and which are sequentially lighted by a corresponding number of voltage sources stepped sequentially out of phase.

This invention is concerned with repetitive sequential connection of a plurality of electrical devices with a source and in one application provides a system which simulates a sound source moving from point to point along a defined closed path of travel. The invention is especially useful with musical circuitry for successively and repetitively keying a plurality of physically displaced speakers and for adding tremolo and vibrato effects to sounds produced by electric organs or the like.

Various mechanical means are employed in electric organs for introducing tremolo or vibrato. Generally, such means are directed to orbital movement of a sound source whether in the form of a speaker which is rotated or of an opening of a rotary horn or baffle which registers with a stationary dynamic speaker. In any event, such apparatus is bulky and introduces heat, electrical, mechanical inertia, rumbling and other well known operating and maintenance problems. Furthermore, an analysis of sounds coming from such apparatus reveals a complex mixture of varying tremolo, vibrato, Doppler and other effects. The vibrato and tremolo components are generally not controllable either individually or independently. Desired radiation patterns are not easily obtainable. Frequency response and power handling capabilities are limited.

An object of the present invention is to provide a circuitry and speaker system for simulating a moving source of sound.

A further object is to provide a circuitry and speaker system which simulate a moving source of sound without requiring physical motion of the source.

A further object is to provide a circuitry for successively and smoothly keying a plurality of physically displaced speakers to a tone source such that each speaker is connected in turn to the source to simulate a sound moving from speaker to speaker.

A further object is to provide such a keying circuitry in which isolation is obtained between the keying circuitry and the audio controlled by such circuitry so as to prevent or minimize extraneous noise created in the keying circuitry from reaching the audio.

Another object is to provide a circuitry and system for simulating a moving source of sound which can be produced in a relatively compact form.

Another object is to provide a circuitry and system in electrical musical instruments or the like for producing vibrato and tremolo effects that can be individually controlled.

Another object is to provide an improved sequential keying circuitry utilizing light sources and light sensitive impedances suitable to sequentially keying devices such as speakers in electrical musical instruments or the like.

Another object is to provide an electronic system for

simulating a moving source of sound with a plurality of speakers but which requires only one power amplifier.

The foregoing and other objects will appear from the following description and drawings, in which:

FIGURE 1 is a block diagram of an electric organ system incorporating the invention.

FIGURE 2 is a more detailed circuit diagram following the FIGURE 1 system.

FIGURE 3 illustrates a cabinet-speaker arrangement useful to the invention employing four speakers.

FIGURE 4 illustrates a cabinet-speaker arrangement useful to the invention employing three speakers.

FIGURE 4A illustrates a three-speaker "phantom four speaker" circuit.

FIGURE 4B illustrates a two-speaker "phantom four speaker" circuit.

FIGURE 5 illustrates an alternate circuit providing means for changing the speaker sequence.

FIGURE 6 is a generalized diagram of the invention employing light sensitive devices and applied to general purpose sequential keying.

FIGURE 7 is a more generalized diagram applicable to devices other than those which are light sensitive.

The invention is illustrated in FIGURE 1 in connection with an electric organ and with a group of four speakers labeled **1**, **2**, **3** and **4** which it is desired to sequentially and repetitively connect in the same order (that is, 1, 2, 3, 4) to an organ tone generator-amplifier **10**. That is, the object of the circuitry of FIGURE 1 is to make the source of sound seem to rotate by causing it to come out sequentially and repetitively first from speaker **1**, then speaker **2**, then speaker **3**, then speaker **4**, then speaker **1** and so forth. The amplitude variation at each speaker is smooth and blends with the last and next succeeding speaker. The speakers themselves should be understood as being physically displaced as illustrated by FIGURE 3 in which **15** represents a suitable speaker cabinet containing the respective speakers **1**, **2**, **3** and **4** physically displaced 90° apart around the inside walls of the cabinet. As brought out in later description the physical displacement of the speakers may be at other than 90° to achieve different rotative effects.

Each speaker has a connection with the tone generator and each such connection is controlled by a light sensitive impedance. In the example of FIGURE 1, the "rotating" effect is achieved at a tremolo rate, 6 to 7 cycles per second, by varying the value of such an impedance in series with each speaker preferably sinusoidally and at the tremolo rate. The impedances take the form of light sensitive resistors provided by photo-conductive tubes **20**, **21**, **22** and **23** connected in series connection respectively with speakers **1**, **2**, **3** and **4**. Delco type LDR–25 photoconductor tubes sold by Delco Division, General Motors Corporation, Kokomo, Ind., are suitable. Tubes **20**, **21**, **22** and **23** are in turn sensitized by corresponding lamps **25**, **26**, **27** and **28** and when illuminated their resistance, of course, drops abruptly from a high value to a low value. The voltages which energize the lamps are derived from corresponding lamp driver circuits **30**, **31**, **32** and **33**. The tubes **20**, **21**, **22** and **23** and the lamps **25**, **26**, **27** and **28** should in any event preferably exhibit short turn-on and turn-off times to achieve the desired smooth following of the sound around its path. The intensity of the type lamp employed should vary linearly with the voltage across the lamp and the impedance of the photo conductor tube employed should approximate a linear function of the incident light intensity so that the modulated tone at the speaker approximates sinusoidal modulation. Of further interest to the present invention is the prior use of variable impedances, namely light sensitive resistors, to gain musical effects as taught by Patent 3,119,890.

It has already been mentioned that the value of the

impedances provided by tubes **20**, **21**, **22** and **23** are varied sinusoidally and at a tremolo rate. This is accomplished by furnishing the lamp drivers **30**, **31**, **32** and **33** with driving voltages which are sequentially stepped 90° out of phase. That is, using the voltage driving lamp driver **30** as a reference such voltage has zero phase deviation as indicated in FIGURE 1. The voltage driving lamp driver **31** is however 90° out of phase with that driving driver **30**; the voltage driving driver **32** is another 90° or 180° out of phase with that driving driver **30**; the voltage driving driver **33** is still another 90° or 270° out of phase with that driving driver **30**.

The described shifting and tremolo rate of energizing lamps **25**, **26**, **27** and **28** and consequent tremolo rate of illuminating tubes **20**, **21**, **22** and **23** is obtained by connecting a suitable, for example voltage controlled, low frequency, in the order of 6 cycles per second, oscillator **38** to suitable phase split circuitry **40**, phase shift circuitry **41**, and phase split circuitry **42** such that four drive voltages phase shifted in the order of zero, 90°, 180° and 270° are provided on the respective lines **43**, **44**, **45** and **46**. A suitable oscillator control **48** for example a voltage regulator may be employed to regulate the precise tremolo rate.

From the description thus far, it will be understood that lamps **25**, **26**, **27** and **28** will light sequentially at a tremolo rate and their respective illuminations will be displaced in phase. This sequential phasing of lamps **25**, **26**, **27** and **28** will in turn cause tubes **20**, **21**, **22** and **23** to be sequentially illuminated and such illumination phase displaced in a like manner. Thus, any audio signal coming out of tone generator-amplifier **10** will be sequentially directed at a tremolo rate to the speakers **1**, **2**, **3** and **4** and in the same order. For this reason, the source of sound coming out of the area where speakers **1**, **2**, **3** and **4** are located will seem to rotate smoothly from speaker **1** to speaker **2**, to speaker **3**, to speaker **4**, back to speaker **1** and so forth.

Organ tone generator-amplifier **10** is of course simply representative of one of the several similar tone generators to be found in the typical electric organ and which by voicing circuitry, not shown, are selectively connected to the audio circuits to be heard. Thus, any tone generator could be connected into the circuitry of FIGURE 1 and its tone made to assume a rotating tremolo effect in the manner just described.

In addition to tremolo or amplitude variation, vibrato or frequency variation may be provided in the usual way as indicated by the low frequency vibrato oscillator **50** and its appropriate control **51**. Thus, both vibrato and tremolo effects may be achieved, and each may be employed and controlled independently of the other. The addition of vibrato is found to simulate the pronounced building up and dying down found in the Doppler effect.

While those skilled in the art will appreciate the many possible ways of deriving the required number of phase shifted voltages from tremolo oscillator **38**, one circuit is illustrated in more detail in FIGURE 2 in which the respective phase split, phase shift and driver circuits of FIGURE 1 are boxed in dashed lines bearing the same identifying numerals. Before proceeding to the details of FIGURE 2 however, brief reference is made to FIGURE 7, which is later discussed, to indicate a very generalized representation of the invention and the fact that magnetic, heat, pressure and other kinds of "sensitive" devices might be employed in place of tubes **20**, **21**, **22** and **23**.

In FIGURE 2, the 90° phase shift circuit **41** is coupled through a capacitor **60** to tremolo oscillator **38** and includes for phase shifting purposes capacitors **61**, **62** and resistors **63**, **64** and **65**. A further coupling capacitor **70** connects phase shift circuit **41** to phase spilt circuit **42** made up of resistors **71**, **72**, **73** and **74** and transistor **75** connected as shown. Resistors **73** and **74** should be equal in value. As indicated in FIGURE 2, a 90° shifted voltage wave arriving on line **76** from phase shift circuit **41** results, with properly chosen values, in two voltage waves shifted respectively to 90° and 270° on lines **77** and **78**. Since phase shifting and operation of such circuitry is well understood and is not claimed, per se, its specific operation is not dealt with in further detail. Other phase arrangements may also be employed. For example, circuitry could be provided to shift plus 45° on one line and minus 45° on another line and each of these phase split to obtain four voltages successively shifted **90°** apart.

The output on line **78** connects through coupling capacitor **80** to the lamp driver **33** which drives lamp **28** through line **81**. As illustrated, typical driving circuitry is employed in drivers **30**, **31**, **32** and **33** and in the phase split circuit **40**. The zero or reference phase voltage derived from phase split circuit **40** is fed on line **82** to driver **30** and through line **83** there is developed the corresponding zero phase driving voltage across lamp **25**. Similarly, line **84** carries the 180° phase voltage through coupling capacitor **85** to driver **32** such that there is developed in line **86** the corresponding 180° phase driving voltage across lamp **27** and line **87** carries the 90° voltage to lamp **26**.

Considering particularly the driver circuit **33** and certain aspects of its operation, the ratio of resistors **34** and **35** determines both the AC and DC voltage across lamp **28** with respect to voltage applied at point **36**. The ratio of resistors **37** and **47** determines the bias on the NPN transistor **52** and in conjunction with resistors **34** and **35** determines the reference voltage applied to point **53**. In place of the type of resistor-capacitor network comprising capacitor **80** and resistors **37** and **47** for developing the voltage at point **36**, point **54** is used as a reference level to supply bias voltage for transistor **55** at point **56**.

Considering the operation of the circuitry and system illustrated in FIGURES 1, 2 and 3, it will be seen that the voltages which energize lamps **25**, **26**, **27** and **28** are successively out of phase by 90°. Accordingly, the time of occurrence of minimum impedance or resistance in tubes **20**, **21**, **22** and **23** is successively out of phase by 90° time intervals. That is, if the tremolo oscillator is running precisely at six cycles per second (6 c.p.s.) each 90° phase interval represents a time of one twenty-fourth of a second ($\frac{1}{24}$ second). In this example, the maximum brightness of the lamps **25–28** will be successively phased $\frac{1}{24}$ second apart and the time of minimum impedance in tubes **20–23** will be successively phased $\frac{1}{24}$ second apart. As indicated by the drawings, each lamp is biased with direct current (DC) voltage to overcome the two brightness maxima common to an alternating current cycle. This DC bias also sets the level of modulation. With such condition and with the organ tone generator-amplifier **10** in operation, it will be seen that the source of maximum sound intensity will sound as if it is moving from speaker **1** to speaker **2** to speaker **3**, to speaker **4** and back to speaker **1** at $\frac{1}{6}$ second per cycle intervals, this being a tremolo type sound effect.

With reference to the phasing of the impedance or resistance in tubes **20**, **21**, **22** and **23**, it is noted that it is preferable to achieve a true sinusoidal phasing. However, a periodic wave which in fact departs substantially from a sinusoidal wave will give pleasing effects. The described rate of "rotation" can of course be controlled by the tremolo oscillator control **48** since the lamp "frequency" or rate at which maximum lamp intensity moves from lamp to lamp (lamps **25–28**) is controlled by control **48**. Accordingly, the rate at which minimum impedance moves from tube to tube (tubes **20–23**) is also controlled by control **48** which means that the rate of "rotation" of the sound originating in tone generator-amplifier **10** and coming from speakers **1**, **2**, **3** and **4** is controlled by control **48**, the net effect being to introduce a rate controllable tremolo effect in the sound ultimately heard by the listener.

In addition to introducing the tremolo effect, the organ tone generator-amplifier **10** may be simultaneously controlled by a vibrato oscillator **50** and its associated control **51** such that the audio signals entering line **90** will

have previously been subjected to vibrato or frequency control at a vibrato rate. Oscillators **38** and **50** may be operated independently or may be synchronized as indicated by the connecting line **58**. One oscillator only may be employed for both frequency and amplitude modulation. With the system operating under the influence of both tremolo and vibrato it thus becomes possible to produce a sound simulating the well known "Leslie" effect. Depending on the precise sound effect desired, attention must be given to such variables as physical location of the speakers, tremolo and vibrato frequency values and phase displacement of the tremolo and vibrato frequencys.

Several distinctions will be noticed between the present invention and the usual Leslie system. In particular the present invention has no physically moving parts and no mechanical, inertia or mechanical wear problems. Additionally, the tremolo and vibrato components are individually and independently controllable in the present invention whereas such components become mixed in the conventional Leslie system without any form of independent control or regulation being available. Another aspect of the present invention is to be seen in the fact that the lamp-photo-conductor tube arrangement effectively isolates the audio from the tremolo control circuit. Consequently extraneous noise in the control circuitry which might arise in the tremolo oscillator, phase shift, phase split or lamp driver circuits is not introduced into the audio. It can also be seen that sound patterns can be controlled by positioning the speakers and modifying the speakers as desired. Only one amplifier is required and without the complexity of a rotating speaker system, proper attention can be paid to the speaker baffling and loading so that greatly extended frequency response and power handling capabilities can be obtained.

While one of the main objectives of the invention is that of eliminating moving mechanical parts, it will be apparent to those skilled in the art that the impedance offered by tubes **20**, **21**, **22** and **23** can be varied mechanically by a typical lamp and rotating shutter arrangement. For example, by physical placing the photoconductor tubes in appropriate physical positions and utilizing a properly shaped shutter and shutter aperture in conjunction with an appropriately placed lamp, a mechanical shutter system as taught by various prior patents such as 3,003,383 and 3,119,890, may be used to replace the previously described electronic modulating and phase splitting elements.

As an alternative to employment of four speakers, three speakers may be employed in a cabinet as illustrated in FIGURE 4. In such case speaker **1** may be connected to both lines **95** and **97** to receive sound through lamp **22** as well as lamp **20**. It then effectively acts as two sources of sound 180° apart. In order to preserve the allusion of three dimensions it is desirable to shift the phase of the "phantom fourth speaker" by 180°. FIGURE 4A illustrates an applicable circuit employing a grounded center tap transformer **49**. A phantom four speaker arrangement utilizing two of the speakers and the center tap transformer **49** is illustrated in FIGURE 4B. With particular regard to the two-speaker circuit array it is important to note that a complete nulling of sound might be achieved because of phase relations and a balanced modulator action which would eliminate the "carrier" i.e. the musical notes being played. To avoid this, an unbalanced modulator action should be sought by simulating the 180 degree speaker with a reduction of level. Greater numbers of speakers, not shown, than four may be employed. For example, eight speakers phased 45° apart may be employed in connection with corresponding phase shifting networks to produce eight lamp drive voltages phased 45° apart.

As shown in FIGURE 5, the output lines **95**, **96**, **97** and **98** coming respectively from tubes **20**, **21**, **22** and **23** may be connected to a selector switch **100** such that any such output line can be connected to any speaker. Selector switch **100** may for example be a multi-position, multi-wafer switch arranged so that each switch position corresponds to a particular speaker sequence. In this way the speakers may be sequenced in orders other than 1, 2, 3, 4 for special effects. For example as illustrated in dashed lines in FIGURE 5, a selector switch position could connect speaker **1** to line **97**, speaker **2** to line **96**, speaker **3** to line **98** and speaker **4** to line **95**. In this case, the speakers would be sequenced in the order 4, 2, 1, 3.

In FIGURE 6, the circuitry and system of the invention is reduced to a diagram illustrating general application of the invention, based on light sensitive devices, to a plural group of electrical devices **105**, **106**, **107** and **108** connected through a selector switch **109** to corresponding photo-conductor tubes **110**, **111**, **112** and **113** fed by a drive source **114**. An oscillator **120** controlled by a suitable control **121** feeds a multi-phase shifting and driver circuit **122** connected to drive in a repetitive sequential phase relation lamps **123**, **124**, **125** and **126**. The comparison between this generalized application of the invention and the musical instrument system using the invention will be seen immediately in that the driven devices **105–108** compare to the speakers **1–4**, the drive source **114** compares to the tone generator-amplifier **10**, the oscillator **120** compares to oscillator **38**, the multi-phase shifting and lamp driver circuitry compares to the circuits **40**, **41**, **42** and **30–33** of FIGURES 1 and 2. That is, the invention, in a general sense, is adapted to a plural group of electrical devices whether speakers or other electrical devices, which it is desired to connect each through a series variable impedance to a common drive source, whether a tone signal or other source, in a repetitive sequential relationship and in which the amplitude of each device builds up and dies according to a periodic wave, preferably sinusoidal.

FIGURE 7 illustrates the invention in a somewhat more general sense as applied to simulated sound rotation. As previously mentioned, tubes **20–23** may be looked upon simply as being "sensitive" devices and lamps **25–28** and their associated phasing and drive means may be looked upon as "sequential impedance phasing means" compatible with the character of the lamp's sensitivities. Thus, other "sensitive" devices such as magnetic, heat, pressure and the like may be employed with compatible sequential impedance phasing means. As illustrated in FIGURE 7, the invention as applied in broad terms to moving sound source simulation may be reduced to a basic system employing a plurality of speakers such as the speakers **130**, **131**, **132** and **133** connected in parallel to a tone generator **135** through a single amplifier **136** and a plurality of variable impedances, one for each speaker, **137**, **138**, **139** and **140**. A control means **141** labeled "sequential impedance phasing control" which is compatible with the character of the impedances may be employed to sequentially and smoothly vary the values of the impedances in some predetermined order and phase and at some predetermined frequency such that there is a smooth transistional rotation from speaker to speaker. Control means **141** may of course take many forms and the lamp, lamp driver and phase control illustrated in the drawings all refer to a light sensitive type system whereas a comparable system following the invention might be based on magnetic, heat, pressure or other form of sensitivity and still realize the unique sequential keying and rotative character of the invention.

Thus, while a specific embodiment of the invention has been described, it will be apparent that various modifications may be made without departing from the spirit and scope of the invention as set forth in the claims.

What is claimed is:

1. In an electric musical instrument including a tone generator productive of a tone signal of constant phase; a plurality of speakers connected in parallel with each other and as a group in series with said generator; a light sensitive impedance in series with each speaker and forming an electrical path directly connecting such speak-

er and said generator, each such impedance being effective when illuminated to complete said path and pass only said signal unchanged in phase and when not illuminated to open said path and block said signal; a light source for each impedance and being effective when energized to illuminate such impedance; a source of energizing voltage for each light source, each said voltage source being developed from a common control source and being productive of continuous periodic wave voltages of the same predetermined frequency but sequentially stepped out of phase whereby to cause a repetitive sequential and smoothly varying energization of said light sources and smoothly varying illuminatin of said impedances, all of said speakers thereby being sequentially connected to and disconnected from said generator in the same sequential phase relation as said voltages and in the repetitive order in which the respective speaker connections and disconnections are made to produce with each speaker an audible tone electrically in phase with said signal and a sound whose source moves smoothly from speaker to speaker in a corresponding sequence.

2. A combination according to claim 1 wherein said common control source comprises an oscillator source operative at tremelo frequency and said predetermined frequency comprises said tremelo frequency.

3. A combination according to claim 2 including a vibrato oscillator connected to said tone generator such that said sound coming from said speakers exhibits in addition to tremelo the vibrato effect.

4. A combination according to claim 2 including a selector switch between said speakers and impedances enabling the circuits between impedances and speakers to be changed and thereby change the sequence in which said speakers are connected to said tone generator.

5. A combination according to claim 2 in which said plurality of speakers comprise four speakers and said energizing voltages comprise four voltages sequentially phase shifted 90 degrees apart.

6. A combination according to claim 2 in which at least one of the speakers has more than one said connecting impedance path to said generator and is thereby made responsive to the effect of more than one of said impedances.

7. A combination according to claim 2 in which said plurality of speakers comprises three speakers and use of said three speakers has two of said impedance paths and is thereby made responsive to two of said impedances.

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