Oct. 26, 1965 R. E. WILLIAMS 3,214,507

PHOTOELECTRIC ORGAN

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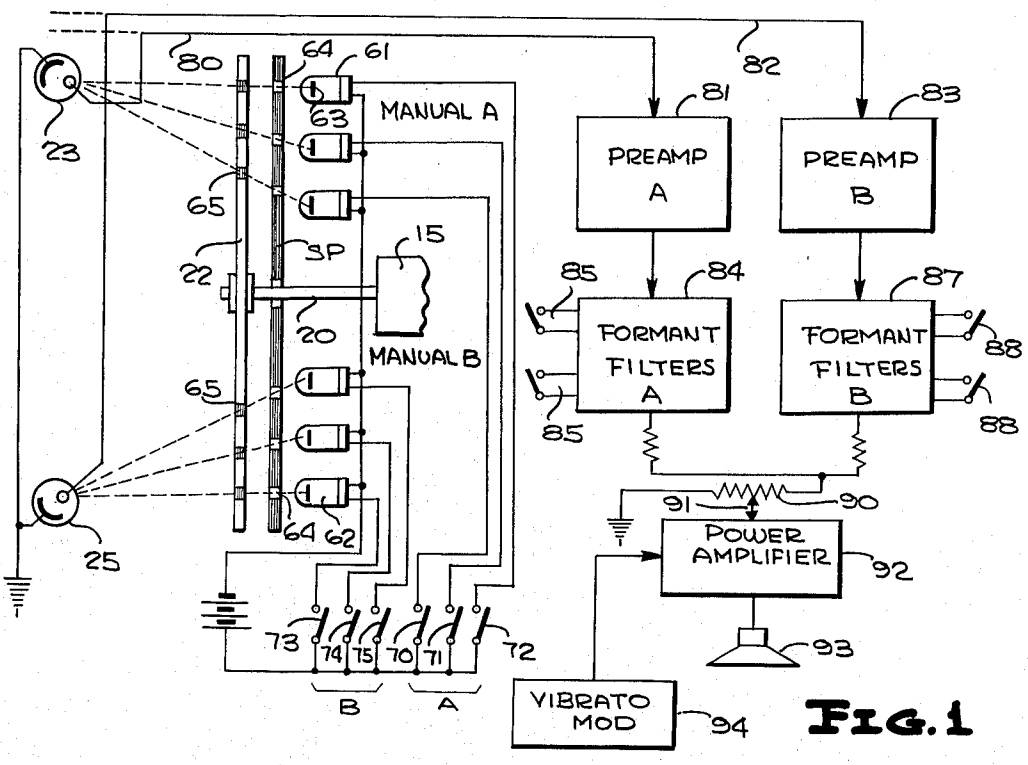


FIG. 1

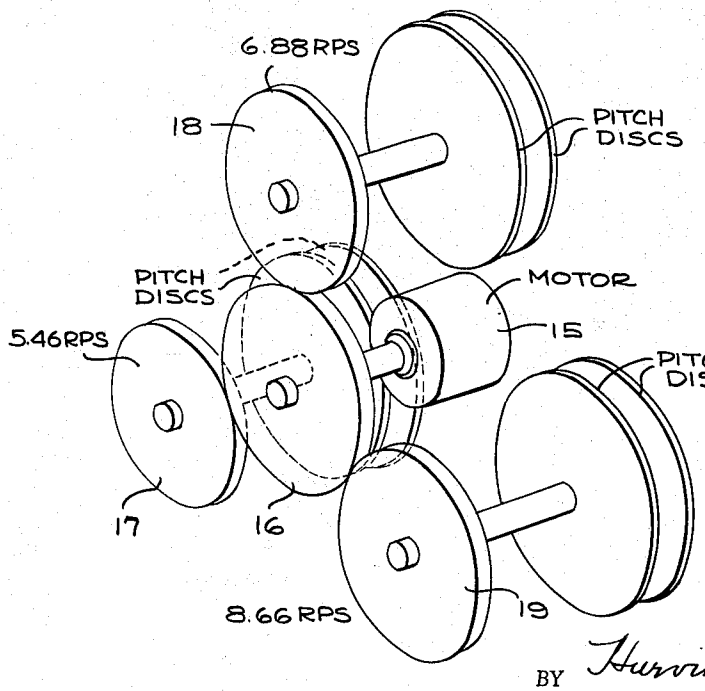


FIG. 4

INVENTOR
RICHARD E. WILLIAMS

BY Hurwitz and Rose

ATTORNEYS

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FIG. 2

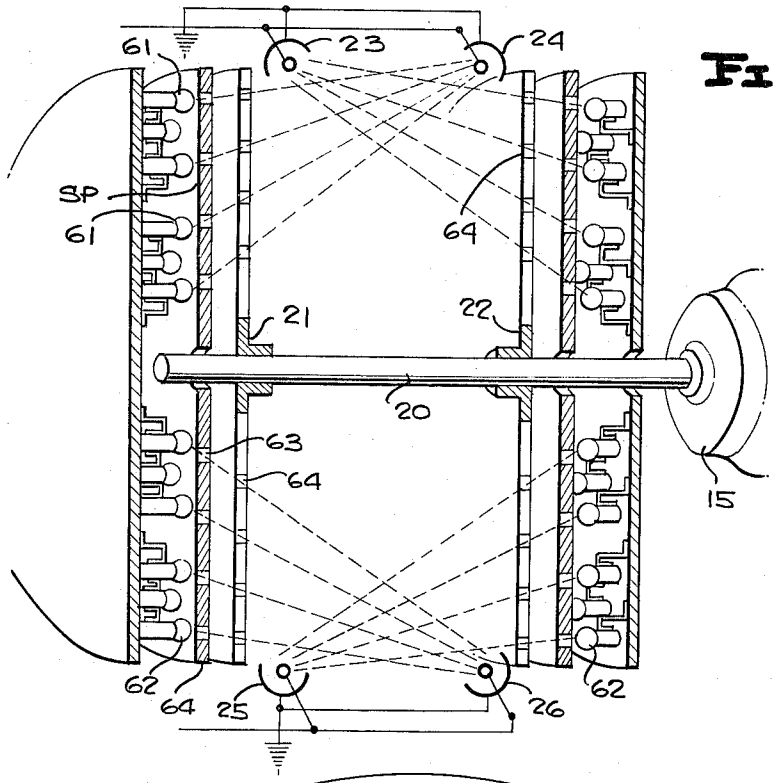
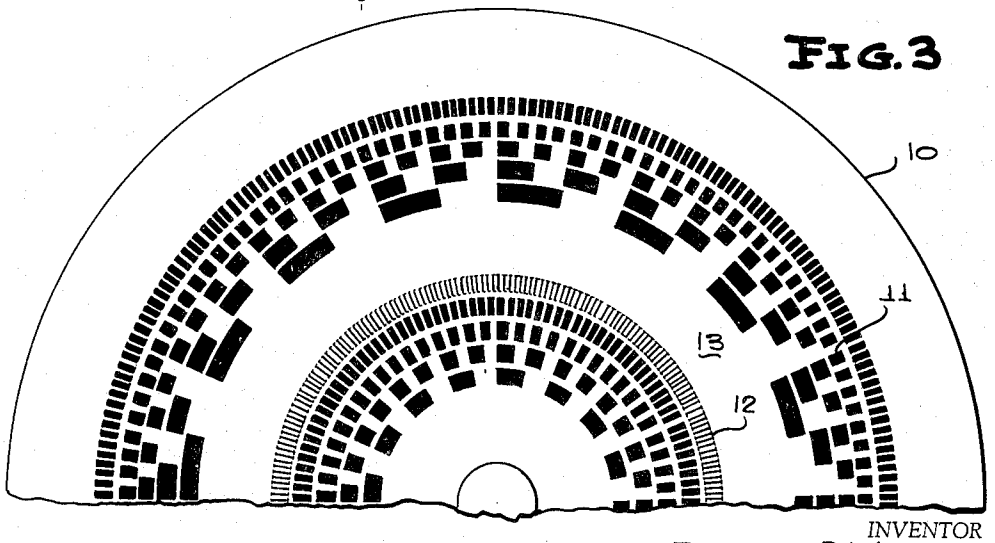


FIG. 3



INVENTOR
RICHARD E. WILLIAMS

BY Hurwitz and Race

ATTORNEYS

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FIG. 5

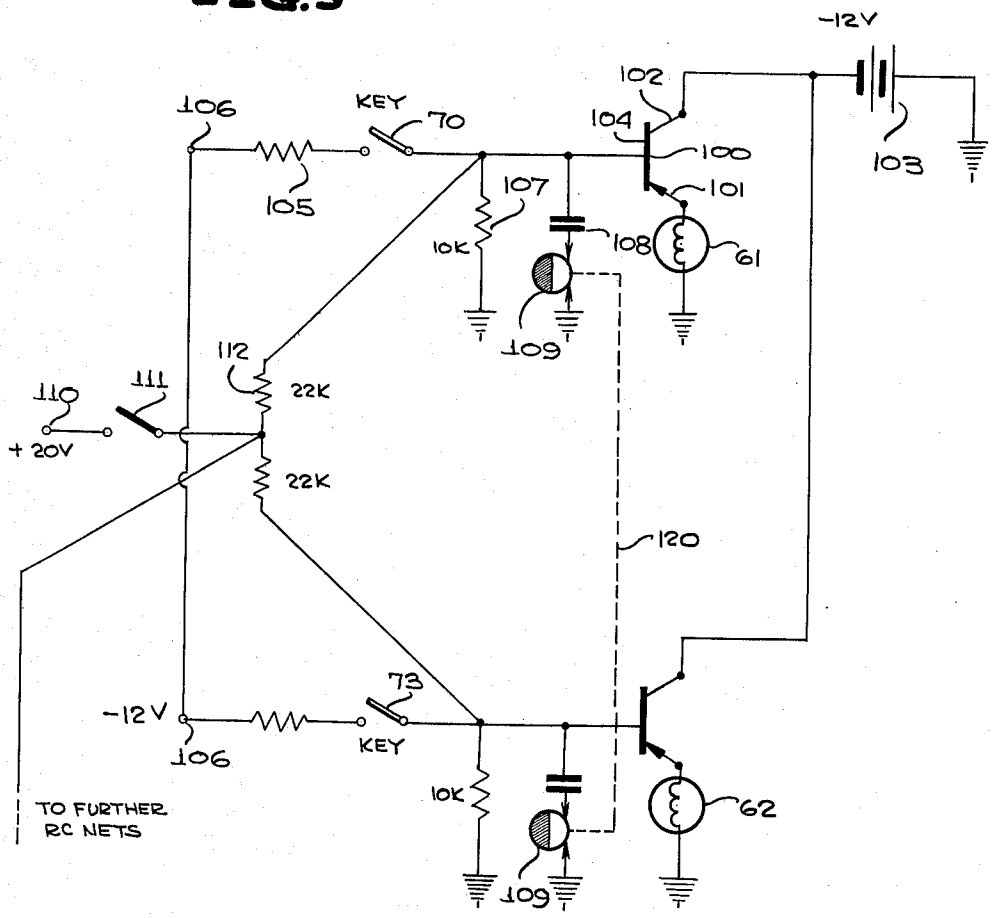
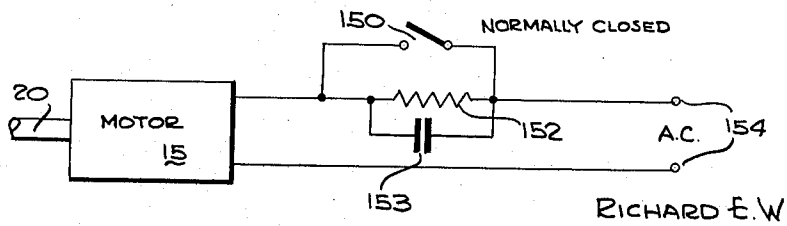


FIG. 6



INVENTOR
RICHARD E. WILLIAMS

BY Harvitz and Race

ATTORNEYS

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3,214,507

PHOTOELECTRIC ORGAN

Richard E. Williams, Fairfax, Va., assignor to Scope, Inc., Falls Church, Va., a corporation of New Hampshire

Filed Mar. 21, 1962, Ser. No. 181,267
11 Claims. (Cl. 84—1.18)

This application is a continuation-in-part of my application for U.S. patent, S.N. 10,829, filed February 3, 1960, now Patent 3,140,337, and entitled "Photoelectric Organ."

The present invention relates generally to electronic musical instruments, and particularly to electronic musical instruments which employ photoelectric tone generators.

In principle, photoelectric musical instruments generate tones by utilizing recorded tone or pitch patterns to modulate light passing to one or more photoelectric cells. The tone or pitch patterns may be of variable density or variable area type, and the techniques involved are in some respects similar to those employed in recording and reproducing sound on film. A large number of systems have been conceived in the past for generating photoelectrically the large number of tones required in commercial electronic musical devices, and a wide variety of techniques have been developed for this purpose. For example, pitch or tone discs have been employed. Such discs are usually entirely clear or translucent except for the presence of a large number of opaque waveform patterns existing in concentric bands on the disc. If a narrow beam of light is focused on one of these bands as the disc rotates, and if a photoelectric tube is placed on the other side of the disc to intercept the light, light passing through the bands is modulated by the variations of opacity of the band, and the amount of light reaching the photoelectric tube varies in accordance with the area of clear band between the light source and the photoelectric tube. Accordingly, the phototube output current varies in exact accord with the shape of the opaque waveform pattern. If the disc is turned at a sufficiently rapid rate so that the variations of photoelectric tube current occur at an audio rate, the output current from the tube may be amplified and acoustically radiated. Key controlled systems may be provided for selectively illuminating several bands or pitch tracks, so that by suitably manipulating the keys musical selections may be generated.

Modern electronic organs make provision for various effects which are musically pleasing. Among these are the effects usually identified by the nomenclature "sustain" and "glissando." The "sustain" effect involves a gradual decay of the amplitude of sound produced by the organ when the organ keys are released. The "glissando" effect involves a sliding frequency shift which can be introduced at will.

It is feasible to provide a sustain effect, in a photoelectric organ utilizing keyed light sources in conjunction with one or more pitch discs, by connecting a sufficiently large condenser across each source. Thereby, the condenser discharges through the light source, usually a lamp, after the energizing circuit for the lamp is broken by release of a key switch, introducing a time delay. However, the light source is a lamp and is therefore a low resistance circuit, so that provision of a sufficiently long decay to be musically effective entails use of an inordinately large condenser.

According to the present invention, each lamp is supplied with operating current through a transistor connected as an emitter follower. The base circuit contains a parallel RC delay circuit which provides sustain effect, and which can employ a relatively small condenser in conjunction with a relatively large resistance. Additionally, keying current, instead of being equal to lamp current, is equal to the current drawn by the resistances of the RC circuit, which serves to enchance performances of the key switches.

The pitch discs of the present invention are driven by a highly over-rated shaded pole motor, which runs at a speed which is a direct function of applied voltage. According to the invention a resistance is connected in series with the motor, which is normally shorted by a switch. Glissando effect is introduced at will, by opening the switch and then closing same. Opening the switch reduces the voltage on the motor, causing deceleration. Reclosing the switch effects acceleration. The sequence of operations provides the desired glissando. The total change in speed is approximately that required to effect a half tone change in pitch.

It is, accordingly, a primary object of the invention to provide tonal effects in photoelectric organs.

It is another object of the invention to provide a novel system for effecting sustain effects in photoelectric organs employing selectively keyed lamps and a pitch disc as tone generators.

It is a further object of the invention to provide a system for generating glissando effects in photoelectric organs employing motor driven pitch discs as tone sources.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a schematic circuit diagram of a photoelectric organ according to the present invention;

FIGURE 2 is a partial view in perspective of a photoelectric tone read-out system, according to the present invention;

FIGURE 3 is a partial view in plan of a tone disc according to the invention;

FIGURE 4 is a view in perspective of a drive mechanism for the plural tone discs of the invention;

FIGURE 5 is a schematic circuit diagram of a modified lamp keying circuit, introducing sustain effect; and

FIGURE 6 is a schematic representation of a glissando circuit.

The several tone discs of the present invention may be fabricated according to the general method disclosed in my co-pending application, Serials No. 753,354, entitled Photoelectric Organ and filed August 5, 1958, making such quantitative modifications as are required by the disc speeds and tone tracks of the present invention, specified herein.

Reference is made to FIGURE 3 of the accompanying drawings, wherein is illustrated a portion of a pitch disc **10**, as finally recorded and developed. Two sets of tracks **11** and **12** are illustrated, each set comprising five octave related tracks of a given nomenclature, and the two sets being adjacent in nomenclature. Six discs are utilized, to provide for twelve nomenclatures. Of the six discs, half are designated A discs and half B discs. The A discs each contain five tracks rooted on **16** wave length representations and five tracks rooted on **17**, but separate ones of the A discs are rotated at different speeds, i.e., 5.46 r.p.s., 6.88 r.p.s., and 8.66 r.p.s. The B discs contain each five tracks rooted on **18** and five tracks rooted on **19**, and are respectively rotated at the same speeds as the A discs, in pairs. Accordingly, one A and one B disc rotate at 5.46 r.p.s., one A disc and one B disc at 6.88 r.p.s., and one A disc and one B disc at 8.66 r.p.s.

The A disc, rotating at 5.46 r.p.s., has recorded thereon all tones having the nomenclatures F, F♯, and the B disc rotating at 5.46 r.p.s. all tones having the nomen-

clatures G, G♯, and in general the tones are distributed among the discs according to the following table:

Speed	Tone Disc A	Tone Disc B
5.46 r.p.s.	F, F#	G, G#
6.88 r.p.s.	A, A#	B, C
8.66 r.p.s.	C#, D	D#, E

The tracks are accordingly all re-entrant, because based on integers, and yet only two different pitch discs are utilized.

The tracks **11** and **12** of the same nomenclature are closely spaced radially, but a considerable radial gap **13** subsists between the set of tracks **11** and the set of tracks **12**. Thereby, if read-out occurs with some inaccuracy of any single tone track, only octave related frequencies can be inadvertently introduced, but not tones of adjacent nomenclature.

The mode of driving the tone discs is illustrated in FIGURE 4 of the accompanying drawings, wherein **15** is a synchronous electric motor, suitably geared down, and which rotates a central drive disc **16**, secured on the shaft of motor **15**. The central drive disc **16** frictionally drives three driven discs **17, 18, 19**, at the peripheries of the respective discs, and the ratios of disc diameters of the latter are selected to provide the required driven disc speeds, i.e., 5.46 r.p.s., 6.88 r.p.s., and 8.66 r.p.s., respectively, for the several discs **17, 18** and **19**.

The several pitch disc pairs are secured to shafts common to the driven disc **17, 18, 19** and the angular separations of the driven discs **17, 18, 19** is 120.

Proceeding to FIGURES 1 and 2 of the accompanying drawings, a typical driven disc **17** is illustrated, having a shaft **20**. On the shaft **20** are two tone discs, **21, 22**, i.e., one A disc and one B disc, for rotation with driven disc **17**. Located between the tone discs **21, 22** adjacent their peripheries, are four photoelectric cells **23, 24, 25, 26**. The photoelectric cells **23, 25** pertain to and face the pitch disc **22**, and the photoelectric cells **24, 26** pertain to and face the pitch disc **21**.

A plurality of lamps is provided, there being specifically one lamp for each key of a first manual of an organ, and one lamp for each key of a second manual of an organ, in a two manual organ.

Lamps pertaining to the first manual, i.e. manual A are designated by the reference numeral **61** while those pertaining to the second manual, i.e., manual B are designated by the reference numerals **62**. Each of the lamps includes a filament and specifically a line filament, the filament being aligned with the radii of the pitch discs. The lamps **61** are arranged in the area circumscribed by a semi-circle having a diameter passing through the shaft **20**. Similarly, the lamps **62** are located within the area defined by a further semi-circle having the same diameter. Each of the lamps is associated with a narrow radially elongated slit, as **63**, in a slit plate SP. Each slit and the associated lamp are so located with respect to an associated pitch track, as **65**, of a pitch disc, as **22**, that light from the lamp passes through a slit **64** and thence through the required pitch track, as **65**, and thence to a photocell as **24** or **25**. The A manual lamps **61** are associated with photocell **23**, and illuminate only that photocell, while the B manual lamps are associated with a separate photocell **25**, and illuminates only the latter.

In general, each separate lamp as **61** or **62** is associated with a single track, but the tracks serve a double function, in that one lamp of the A manual lamps **61** and one lamp of the B manual lamps **62** are associated with each one of the tracks **65**. It follows that the photocells **23**, and **24** may provide identical tonal outputs, i.e., of the same nomenclature and scale position, when suitable keys in the two manuals are depressed, but these identical tonal outputs are provided via separate photocell output channels. Track sharing in this manner is a feature of economy in the present invention, and not an essential feature, in the sense that duplicate or different pitch discs may be utilized for the separate manuals if desired, and in a complex organ which may employ as many as four manuals, four separate and distinct sets of pitch discs may be employed, or fewer pitch discs may be employed by utilizing tone track sharing.

In order to produce any given tone, an appropriate one of lamps **61, 62** is energized. In FIGURE 1 of the accompanying drawings, I have illustrated three keys **70, 71, 72**, taken from manual A and three keys taken from manual B. It will be observed that the manual A keys **70, 71** and **72** connect separate ones of the lamps of the A group to a source of voltage, while the key actuated switches **73, 74** and **75** pertaining to the B manual, control the lamps of the B group. All the lamps, nevertheless, may be energized from the same source B, or, if desired, lamps pertaining to the separate manuals may be provided with separate power supplies. Electrical signals generated by the photocell **23** in response to tone modulated light originated by any of the lamps **61** pertaining to manual A are supplied via lead **80** to a pre-amplifier **81**, which pertains to manual A only. Similarly, the output of photocell **25** is applied via a lead **82** to a pre-amplifier **83** which pertains to the B manual only. The output of the pre-amplifier A is passed through a group of formant filters **84** which pertains to the manual A, and separate filters of which are selected by means of the stop switches **85**. Similarly, the output of pre-amplifier B is applied to a group of formant filters **87** which are selected by means of stop switches **88**. The outputs of the formant filters **84, 87** are combined in a resistance **90** which includes an adjustable slider **91** acting as a volume control for the system.

The combined outputs on the slider **91** are applied to a power amplifier **92** and thence to an acoustic radiator **93**, such as a loudspeaker. To the amplifier **92** is also supplied vibrato modulation deriving from modulator **94**, which modulates the frequency of output of the amplifier **92** at a vibrato rate suitable to the system. It is important to note that the vibrator rate employed can no longer be equal to the rate of rotation of all the pitch discs, since the latter are not identical. In my prior application, hereinabove referred to, the vibrato rate employed was equal to the rate of rotation of the single disc employed. In accordance with the present invention, any variation of speed of the pitch discs results in internally generated vibrator effects, but these are not at the same frequency as the vibrato effects introduced by the modulator **94**, in general. A vibrato frequency may be employed equal to the rotational rates of one of the pitch discs, the other then being unequal. Nevertheless, any jitter in the pitch discs is translated into a vibrato effect which is pleasant to the ear.

In the system of FIGURES 1 and 2, since generation of the tones appropriate to any single manual require the utilization of six pitch discs and since each manual includes circuitry for reading out each pitch disc, which in turn includes a photocell, all six photocells pertaining to a manual are connected in parallel, as indicated generally in FIGURES 1 or 2 of the photocells.

An important structural feature according to the present invention resides in the location of the photocells as **23, 24** pertaining to one pair of A and B pitch discs, at locations intermediate the pitch discs. The slit discs **64** then are located outside the pitch discs and the lamp mounting plates and lamps are locate outside the slit plates, as illustrated in FIGURE 2. Electrically considered, then, the signals pertaining to any one manual are identical to signals which might be provided were a single photocell and single pitch disc utilized. They may, therefore, be processed in the manner specified and described in detail in my above referred to application for U.S. patent. Similarly, the total number of lamps employed in the two systems, i.e., the present system and the system of my above

identified application for U.S. patent, may be identical. And accordingly the circuitry utilized for controllably energizing the lamps may be identical in the two systems, and the circuit expedients therein described and illustrated in detail are incorporated herein by reference.

In place of a pair of lamps connected in parallel, as **23, 24**, I may also utilize a single photocell associated with two mirrors, which reflect light deriving from the lamps via the tone tracks to the cell. Also, a single cell, as **23**, may be employed, the remaining cell of a pair, as **24**, being replaced by a mirror which directs light to the cell **23**.

In the system of FIGURE 1, the lamps **61, 62** are selectively energized through key switches **70–75**, inclusive, from a battery or equivalent D.C. source. Since the lamps **61, 62** provide maximum light very quickly after application of current thereof, and cool quickly on interruption of current, no audible sustain effect occurs. In order to provide such effect the several lamps **61, 62** are energized according to the system of FIGURE 5.

Each of lamps **61, 62** is energized through a PNP transistor, as **100**. The transistor is connected in the emitter follower configuration, i.e., the lamp **61** is connected between emitter **101** and ground, collector **102** being connected to a negative D.C. source **103**. The base **104** of transistor **100** is connected in series with a key switch, as **70**, and a protective resistance **105** to a negative D.C. bias source (not shown) supplied to terminal **106**. Connected between base **104** and ground is a parallel RC circuit, including a resistance **107** and a capacitor **108**, the latter being in series with a switch **109**. The resistance **107** may have a value of about 10K.

The transistor **100** is normally non-conductive, since its base is returned to ground and it is in the emitter follower configuration. Closure of key **70** applies an on-keying negative bias to the transistor **100**, which permits current to flow from D.C. source **103** to lamp **61**. Opening key **70**, with capacitor **108** out of circuit, removes the on-keying bias and de-energizes the lamp **61**. These effects occur rapidly. Absent capacitor **108** from the circuit then, operation takes place essentially as in the system of FIGURE 1.

When switch **109** is actuated to connect capacitor **108** to ground, that capacitor charges when key switch **70** is closed On opening the key switch **70** the charge on capacitor **108** leaks rather slowly through resistance **107**, and assuming that a proper time constant has been selected a gradual decay of current to lamp **61** takes place, which gives rise to sustain effect.

The several lamps **61, 62** may all be supplied with identical circuitry, wherefore description of the typical circuit of further circuits, as for lamp **62**, FIGURE 5, is dispensed with as redundant.

It is desirable to provide sustains of at least two different lengths. To this end, a positive voltage terminal **110** is connected via a short sustain switch and a resistance **112**, slightly more than twice as large as resistance **107**, to the RC circuit composed of resistance **107** and capacitance **108**. On closure of switch **111**, then, and regardless of whether or not key switch **70** is closed, a positive bias is placed on base **104**, which serves to maintain transistor **100** cutoff and provides a + charge on condenser **108**, if switch **109** is closed. On closure of key **70** the + charge on condenser **108** is overcome by the −12 v. available at terminal **106** and transistor **106** is keyed on. On subsequent re-opening of the key **70**, the negative charge on condenser **108** leaks off through resistance **107** and this negative charge is, further, reduced by positive charge deriving from terminal **110**, flowing through resistance **112**. The net effect is that of an accelerated discharge of capacitor **108**, to a final voltage which is positive, rather than ground. The total length of time transistor **100** is in conductive state is thus reduced.

The current arrangement is such than any number of lamps, as **61, 62**, may be controlled selectively, each by means of its own transistor, and all the transistors may be biased from three common sources, i.e. collector voltage, long sustain control voltage at terminals **106**, which may all be commonly connected to the same supply, and the terminal **110**.

The several switches **109** are mechanically ganged by link **120**, so that all are simultaneously open or closed, depending on whether or not sustain effect is desired.

Referring now to FIGURE 6, a normally closed switch **150** shunts a resistance **152**, which is further shunted by a click filter condenser **153**. A.C. terminals **154** are connected via resistance **152** to motor **15**.

Motor **15** is a highly over-rated shaded pole motor, and operates with negligible slip and at a speed determined entirely by applied voltage. When switch **150** is opened the voltage on the motor is decreased, and the motor decelerates to a speed which is less than normal, and retains this speed so long as switch **150** is open. The reduction and increase are gradual, and produces a glissando effects, since pitch of all notes is directly proportional to motor speed.

In playing the organ, then, the musician can at will actuate the switch **150** to open position for short time interval, or transiently, introducing a gliding change of pitch downwardly followed by a similar change upwardly to normal pitch.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A sustain circuit for a photoelectric organ, said organ having at least one pitch disc having plural tone tracks, lamps for selectively illuminating said tracks, said lamps being normally deenergized, key switches for selectively energizing said lamps at will, a separate amplifier permanently connected between each of said switches and one of said lamps to energize the one of said lamps when the amplifier is in conductive condition, means normally biasing said amplifiers into off-biased condition, a source of bias voltage, means responsive to closure of each key for connecting said source of on-bias voltage to its associated amplifier so as to bias that amplifier into conductive condition and thereby energize the associated lamp, each of said amplifiers including an input circuit, a separate capacitor and discharge resistance connected in parallel to each other across each input circuit, said separate capacitor and resistance having a discharge time constant of duration sufficient to provide a sustain effect.

2. The combination according to claim **1** wherein said amplifier is a transistor amplifier connected in the emitter follower configuration, the associated lamp being an emitter load for its amplifier.

3. The combination according to claim **1** wherein is further provided means for at will disconnecting all said capacitors from all said amplifiers.

4. The combination according to claim **1** wherein is further provided means for at will applying to all said capacitors a charging voltage of polarity opposite to the polarity of said on-bias voltage.

5. The combination according to claim **4** wherein said voltage of polarity opposite to the polarity of said on-bias voltage is of greater magnitude than said on-bias voltage, and wherein resistance greater than said first mentioned resistance is connected intermediate said means for at will applying said charging voltage to all said capacitors, the ratio of the last named resistances to the discharge resistance being of the order of magnitude of the ratio of said voltages.

6. The combination according to claim **1** wherein an alternating current motor is coupled in driving relation to said pitch disc and arranged for rotating said pitch disc at a predetermined speed determined substantially entirely by the voltage of a source of power connected to

said motor, a resistance connected in series between said source of power and said motor and a normally closed switch connected across said resistance, said resistance having a value selected to reduce the speed of said motor sufficiently to change the pitches provided by said pitch disc approximately a half tone, and the moment of inertia of said motor having a value selected to impart a glissando rate to said change of pitch.

7. A sustain circuit for an electronic organ having a pitch disc, means including a set of lamps for selectively illuminating tracks of said pitch disc, and key switches for selectively energizing said lamps, said sustain circuit comprising a separate amplifier means permanently connected to energize each of said lamps, each of said amplifier means including an output circuit connected to one of said lamps and an input circuit connected to one of said key switches, each of said input circuits including a resistance and a condenser in parallel, the time constant of said resistance and condenser being selected to provide a sustain effect, and means for at will disabling all said condensers simultaneously.

8. The combination according to claim **7** wherein is provided a first source of bias of a first polarity selected to off-bias said amplifiers, a second source of bias of second polarity opposite to said first polarity, means for connecting said first source of bias to each of said input circuits via a different one of said key switches, and means connecting said second source of bias simultaneously at will to all said input circuits in charging relation to the condenser therein.

9. A sustain circuit for an electronic organ having a pitch disc, means including a set of lamps for selectively illuminating tracks of said pitch disc, key switch means for selectively energizing said lamps, a separate amplifier means permanently connected to energize each of said lamps, each of said amplifiers including an output circuit connected to one of said lamps and an input circuit connected to one of said key switches, a source of bias voltage for each of said amplifiers for biasing said amplifier on in response to closure of its key switch, and a delay circuit connected intermediate the input circuit and the key switch of each of said amplifiers, said delay circuits each including a capacitive element connected in parallel to its input circuit, and means for at will discharging the capacitive element.

10. The combination according to claim **9** wherein is further provided means for at will modifying the effective time constant of said capacitive element.

11. A system for introducing musical effects into tones generated by a photoelectric organ, said organ comprising at least one pitch disc having tracks, means for reading out said tracks, a set of keys connected to said means for selecting said tracks, a motor connected to said pitch disc for rotating said pitch disc at a predetermined speed, said motor having a speed determined substantially entirely by voltage of a source of power connected thereto, said system comprising resistance connected between said source and said motor, and switch means for at will shorting out said resistance, said organ further comprising an array of key operated switches, an array of lamps for selectively illuminating said tracks in response to selective actuation of said keys, a separate amplifier connected permanently in energizing relation to each of said lamps, each of said amplifiers including an output circuit connected permanently to one of said lamps and an input circuit connected to one of said key switches, each of said input circuits including a resistance and capacitor in parallel, the time constant of said resistance and capacitor being selected to provide an audible sustain effect, and means for at will disabling all said capacitors, a tone output means connected to said means for reading out said tracks.

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ARTHUR GAUSS, *Primary Examiner.*

GEORGE N. WESTBY, JOHN W. HUCKERT, *Examiners.*