

March 6, 1962

E. M. JONES ETAL

3,023,657

PHOTOELECTRIC MUSICAL INSTRUMENTS AND THE LIKE

Filed Aug. 25, 1955

4 Sheets-Sheet 1

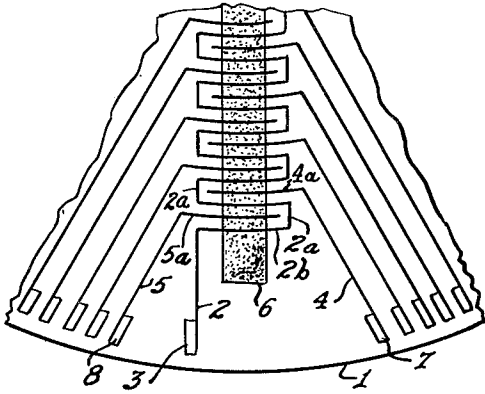


FIG. 1.

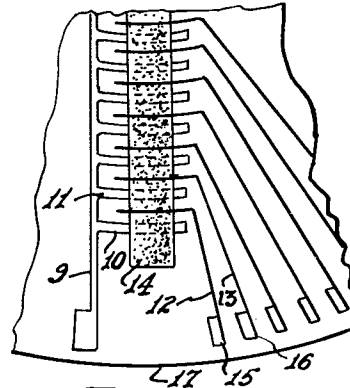


FIG. 2.

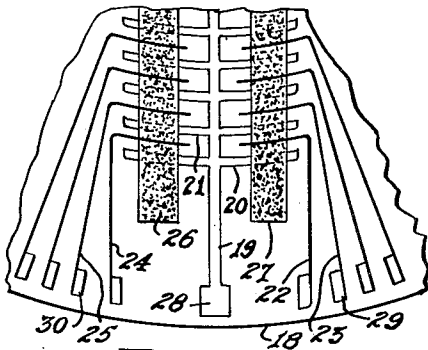


FIG. 3.

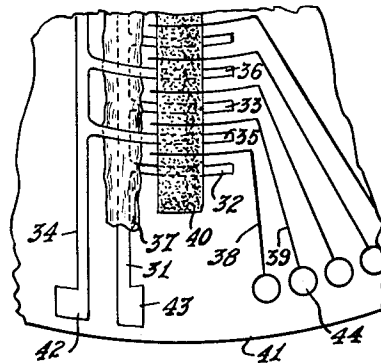


FIG. 4.

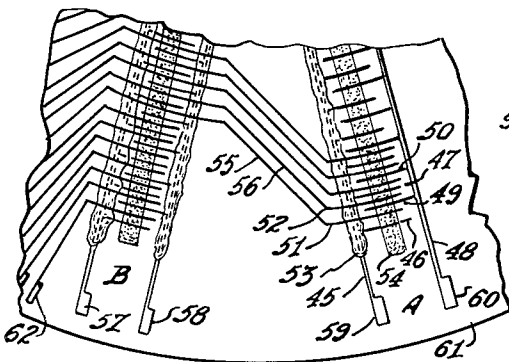


FIG. 5.

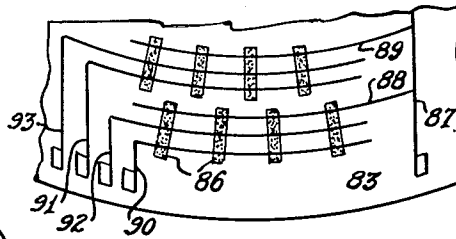


FIG. 6.

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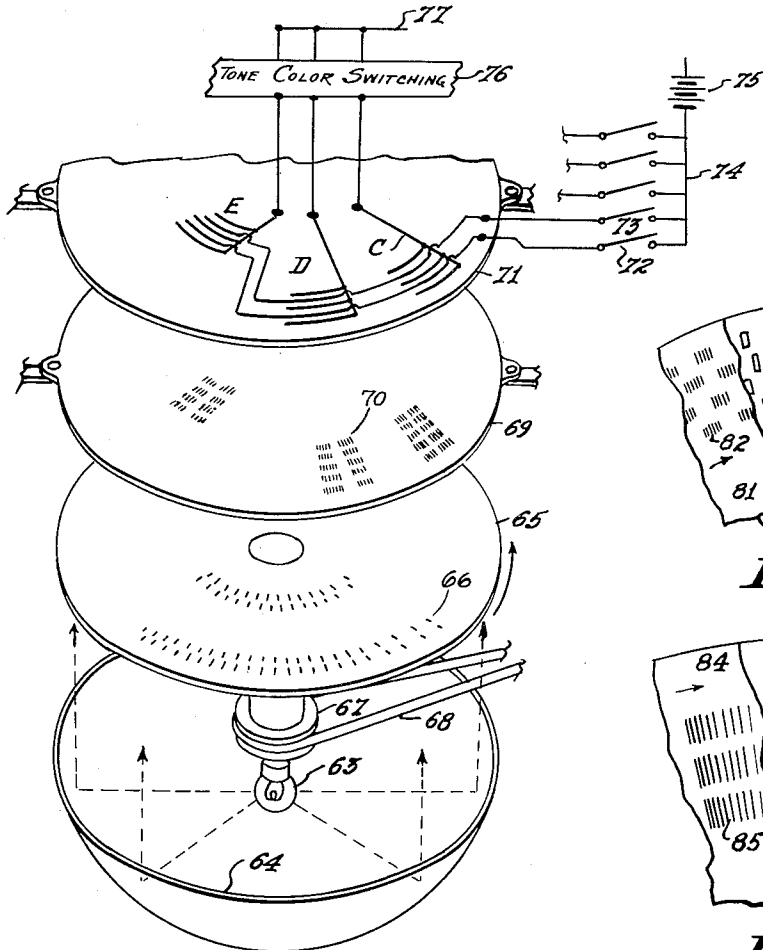


FIG. 7.

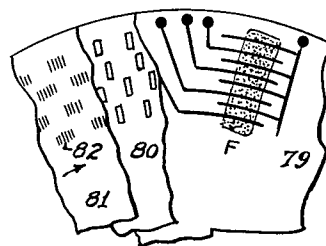


FIG. 8.

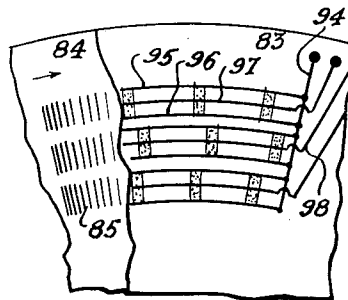


FIG. 9.

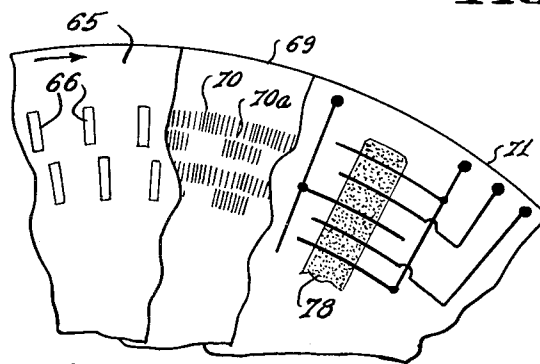


FIG. 10.

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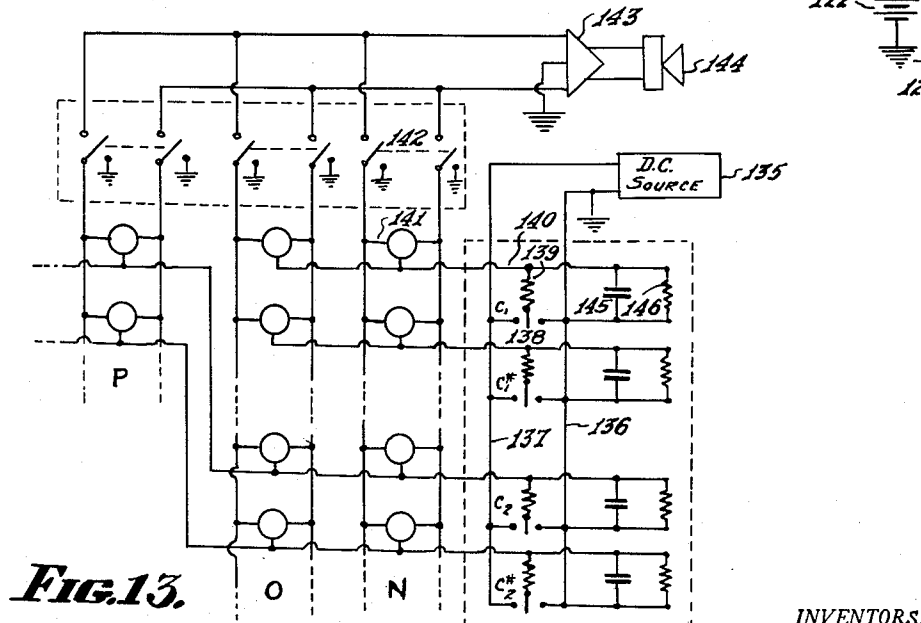
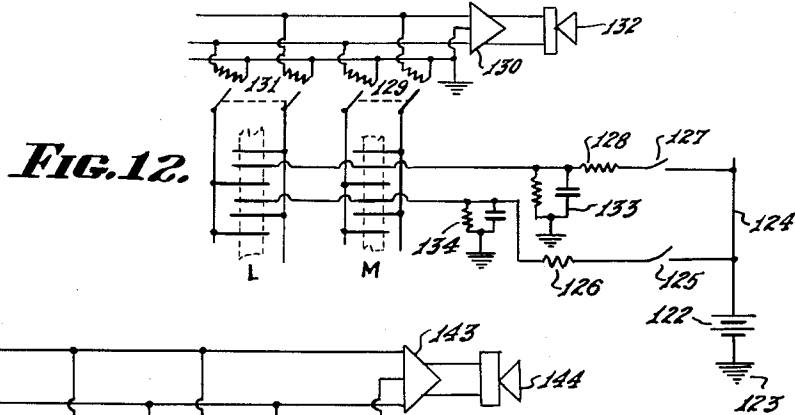
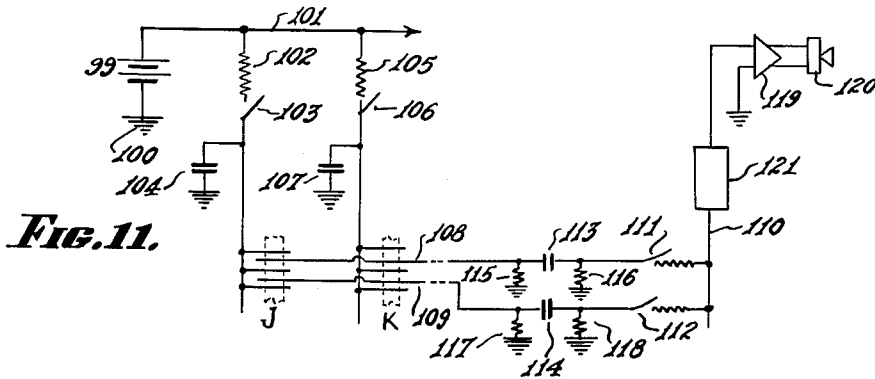
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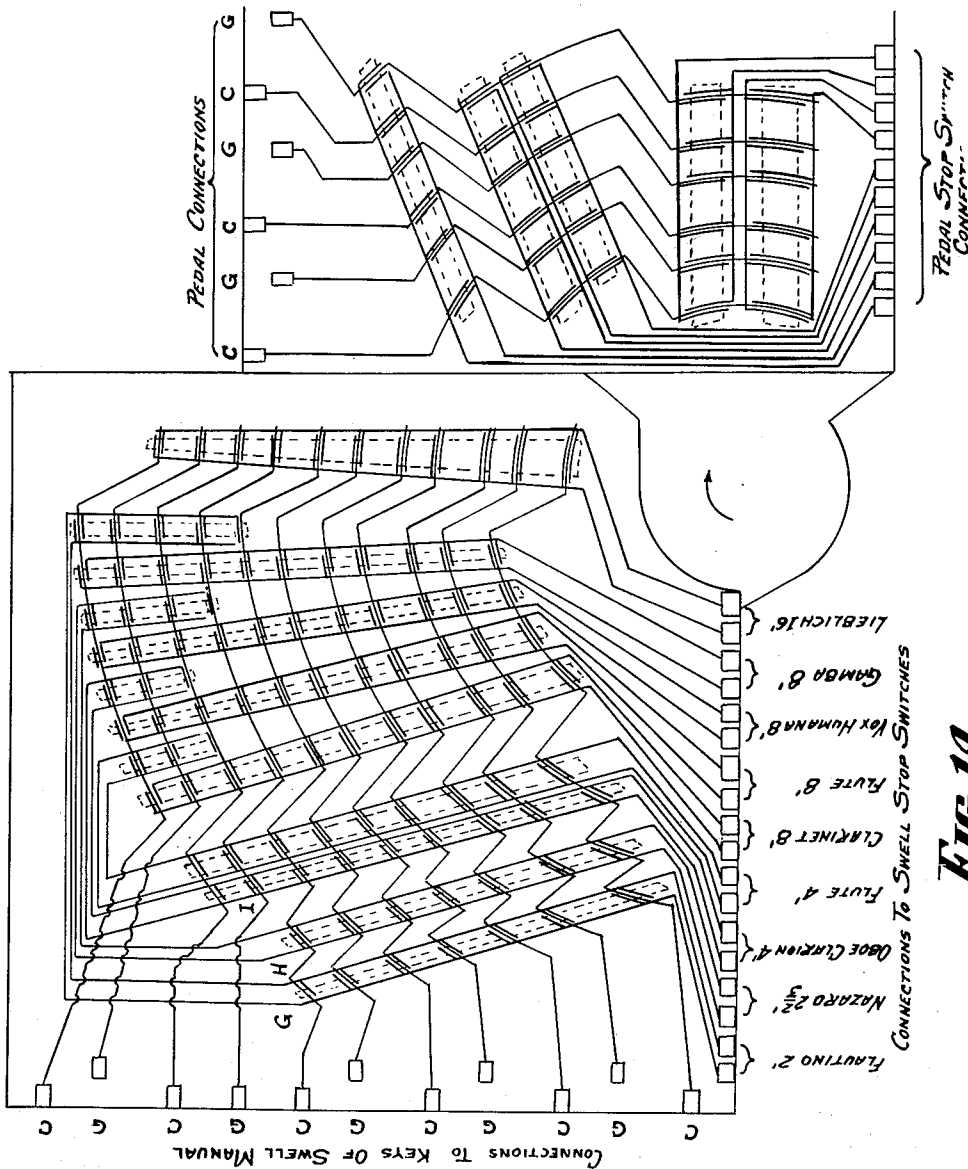
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PHOTOELECTRIC MUSICAL INSTRUMENTS AND THE LIKE

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Filed Aug. 25, 1955, Ser. No. 530,570

17 Claims. (Cl. 84-1.18)

Photoelectric musical instruments, as hitherto most highly developed in the art, (see, for example, U.S. Patent No. 2,576,759 to Edward M. Jones) have made use of a rotating pitch disc to provide the several desired frequencies, a stationary voice disc containing wave form modifying means to provide the several desired timbres, and a shutter mechanism, together with a photocell on one side of the combination and a light source on the other.

Shutter mechanisms have been simplified and perfected (see for example, U.S. Patent No. 2,506,599 to John F. Jordan), and consist in general of a supporting disc or plate and shutter elements actuable to cover and uncover simultaneously a plurality of shutter openings for notes in the same or different registers. The note openings are arranged in groups for the various timbres or voices, and these are controlled in turn by door-like shutters adapted to cover or uncover the separate groups.

Such instruments, in the provision of electrical organs, have certain important advantages. Very beautiful tones may be produced since exact control of the wave forms is possible, and these tones may readily be produced in sufficient number to give a highly flexible instrument. Also, the problem of electrical wiring is reduced to a minimum, since the entire output of the instrument may be picked up by one or a small number of photo cells, which in turn, can be connected directly to an amplifier. At the same time, they have the disadvantage of requiring mechanical connections between the shutter mechanism and each of the playing keys as well as to each of the stop tabs. Thus there will be within the console a complexity of mechanical transmission elements, which is expensive, takes up room, and impedes servicing.

It has hitherto been suggested that an arrangement might be effected whereby the desired individual tones could be selectively derived by electrical circuit means, thus eliminating or simplifying shutter mechanisms, and doing away with the aforesaid mechanical connections. This would require a separate photo cell for each note, and usually each note in each voice, which at the outset is a matter of great expense for equipment. No one has previously suggested any construction for an instrument employing such a system, which is not bulky, unwieldy, and complicated (if the instrument is to have desirable range and flexibility) as well as expensive.

One of the objects of the present invention is the provision of an instrument which will combine the advantages of both systems while eliminating the disadvantages of each.

It is an object of the invention to provide a mechanically simplified and less expensive photoelectric instrument.

It is an object of the invention to provide for the derivation of voices at different pitches from the same keys in a photoelectric musical instrument.

It is an object of the invention to provide electrical keying systems for photoelectric musical instruments, and in particular keying systems which will produce either sustained or transient type tones.

These and other objects of the invention, which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, are accomplished by that construction and arrangement of parts of

which certain exemplary embodiments will now be described. Reference is made to the accompanying drawings wherein:

FIG. 1 is a partial plan view of an array of photo cells on a common support and having one common electrode.

FIG. 2 is a partial plan view of another photo cell array which is electrically similar.

FIG. 3 is a partial plan view of a double photo cell array of the same electrical type.

FIG. 4 is a partial plan view of a photo cell array of a type in which each cell has a polarizing electrode and two other electrodes, the last mentioned electrodes being common to the several photo cells in the array.

FIG. 5 is a partial plan view of a pair of photo cell arrays with cross connections for the simultaneous derivation of tones of different frequency and voice in a single keying operation.

FIG. 6 is a partial plan view of another form of photo cell array.

FIG. 7 is a diagrammatic, exploded view of elements of an exemplary tone and voice generator.

FIG. 8 is a fragmentary diagrammatic showing of a system employing a fixed aperture disc and a moving voice disc.

FIG. 9 is a fragmentary diagrammatic showing of a system employing a moving voice disc and a photo cell disc only, the pitch disc being omitted and the frequency being determined by the placement of individual photo cell elements on the photo cell disc.

FIG. 10 is a diagrammatic showing of a system employing a fixed photo cell disc, a fixed voice disc, and a moving pitch disc.

FIG. 11 is a partial circuit diagram showing an arrangement in which the individual notes and the voices are each selected by separate switches.

FIG. 12 is a partial circuit diagram showing an arrangement in which individual note selection is accomplished by the selective polarization of individual photo cell assemblies.

FIG. 13 is a partial circuit diagram showing a system adapted for the securing of controlled tone envelopes.

FIG. 14 is a diagrammatic showing of one form of photo cell array suitable for use in a photoelectric musical instrument.

The improvements upon which various modifications of the invention hereinafter described are based contemplate the use of one or more arrays of photo cells on a single support; and a consideration of what is involved in this is first in order. In its simplest form, a photoelectric cell comprises a pair of electrodes with a body of light-sensitive material electrically located between them. The photoelectric cells may be of two general types. In one such type, the imposition of light on the light-sensitive material will generate an electric current, which may be amplified and used as such. Simple keying by means of switches can be employed with such devices.

In a second type of photoelectric cell the resistivity or impedance of the light-sensitive material varies upon the imposition of light thereon. In this type of device, the effectiveness of the cell depends upon the application thereto of an electric current from external source, i.e. the cell must be polarized. The variations of the applied current through changes in resistivity can be converted into useful electrical oscillations. This type of photoelectric cell may, if desired, be provided with three electrodes with advantages hereinafter set forth; and the keying for note selection may be accomplished by switches in the leads of the polarizing electrodes.

The invention herein taught is applicable to both types of photoelectric cells.

The invention herein taught has as another of its bases the concept of a combination between a photo cell array on a single support and a series of circuit elements on the same support for connecting or interconnecting the individual photo cells and other circuit elements. This combination, on its single support, partakes somewhat of the nature of "printed circuitry," and portions of it at least may be made by methods appropriate for printed circuitry.

The provision of a photo cell array permits the location of a large number of individual photo cells in a very small space, appropriate to the use of pitch discs and voice discs of feasible sizes; and the nature of the photo cells themselves is such that they are very thin in the direction normal to the support surface, so that the photo cell array, which itself is in the form of a plate, may be approached very closely to such elements as pitch discs and voice discs. The inclusion of circuit elements is also important not only in the elimination of external wiring but also in the confining of the photo cell array to a very small area. As a support or base, a very large number of insulating materials may be employed, including such materials as resinous panels, hard rubber panels and the like. Because of the desirability of dimensional stability in an array containing a large number of small individual photo cells, glass or other vitreous supports are preferred, but the invention is by no means limited to these.

There are various ways in which metallic elements constituting both the electrodes and the interconnecting circuit elements may be imposed upon a suitable base. This may be done by such known means as electroplating, vacuum-vapor deposition, spraying, or the direct adhesion of a preformed sheet or foil of metal to the base. The metal may be selectively applied only in those areas in which its presence is desired. This may be done by printing, by spraying or evaporating, through a stencil, by the application of a suspension of finely divided metal through a silk screen, and in other ways. Where the metal coating is applied generally, unwanted areas of it may be removed by covering the remaining areas with a resist, chemically etching to remove the metal and afterward dissolving off the resist. Such heat treatments may be applied as are desired to unify or treat the metal coating.

In general, an individual photoelectric cell such as herein contemplated will consist of two or more electrode members formed by portions of the metallic coating aforesaid, spaced laterally on the support, the electrode elements being interconnected by a thin layer of the light-sensitive material. As known in the art, the light-sensitive material may consist of or comprise various metals of which selenium is an example, or various salts of which lead sulphide is an example. The light-sensitive layer may be applied in various ways as by spraying, fusion, vacuum-vapor deposition and the like. Beyond what is set forth in the appended claims, the specific nature of the photo cells and of the light-sensitive material does not form a limitation on this invention. To complete an exemplary disclosure, reference is hereby made to an article on page 818 of *Nature* for June 14, 1947, volume 159, entitled, "Lead Sulphide Photo Conductive Cells," by L. Sosnowski et al., and to an article beginning on page 115 of *Journal of Scientific Instruments*, volume 4, 1927, entitled, "The Formation of Films of Lead Sulphide on Glass Surfaces," by H. L. Smith.

A structure comprising a support with spaced metallic electrodes thereon may be completed as a photoelectric cell by imposing a layer of photoelectric substance, e.g. lead sulphide, on the support in such a way as to overlap and interconnect the electrodes in a selected area. The metallic elements forming the electrodes and interconnections may themselves be applied in several increments if desired. This is especially valuable in instances

where one electric conductor must cross another without making electrical contact with it. For example, it is possible to impose a conductive element on a glass or other base surface, then to coat the portion of the conductor at which the cross-over is to be effected with a thin layer of insulative substance, for example, a resin, and then to impose a second conductor which will cross the first in the said area, thus avoiding direct electrical contact between the conductors. In some of the structures hereinafter described, cross-overs are necessary, and they can be effected in this fashion, although where the circuitry will permit, cross-overs are to be avoided by reason of the added expense.

In photoelectric organs, the pitch discs and voice discs are usually so formed that the pitch and voice representations thereon are quite small and quite close together. For example, a pitch disc may be formed with a series of concentric pitch representations, each such representation being, say, not more than $\frac{1}{8}$ of an inch wide in the radial direction, the spaces between the representations being of the same or a lesser dimension. The voice representations on the coating voice disc will be similarly placed and sized. These dimensions do not constitute a limitation on the invention, but are given as an illustration of the fact that in the preferred form of an electrical musical instrument of this type the photo cell array will consist of a large number of individual photoelectric cells each of which is quite small in area, the cells being quite closely spaced. Certain aspects of the invention are not confined to the use of voice discs or pitch discs as will hereinafter be explained; and indeed the photo cell array to which the invention pertains may be used with film representations of voice or frequency indicia, with rotating cylinders and the like.

It has been found that a large number of very small photoelectric cells may be brought together on a single support even to the extent of having one or more common electrodes on the said support; and that the individual photo cells can operate independently of each other and without mutual electrical interference providing each such cell is isolated by an electrode element adequately as hereinafter described. One way in which this may be accomplished is illustrated in FIG. 1 where 1 is, for example, a portion of a glass base. An electrode 2 is deposited thereon having substantially radially arranged portions 2a and circumferentially arranged portions 2b so that the electrode has a serpentine form. The electrode may be provided with a contact element 3 near the edge of the base. Other electrodes are shown as at 4, 5, etc. each comprising a circumferentially arranged electrode portion 4a or 5a lying between adjacent circumferentially arranged portions of the electrode 2. A stripe or deposit 6 of light-sensitive material overlies and interconnects the electrode elements. Each pair of adjacent circumferential portions of the electrode 2 defines a photoelectric cell; and it will be seen that the cells are completely contiguous, while each cell is margined on three sides by the electrode 2. The array of cells extends radially of the base 1; the number of individual cells in the array may be sufficient to encompass the frequency range of the instrument in a given voice; and the support may bear other arrays of photo cells for other voices. Each of the electrodes 4, 5 etc. may be provided with a contact element 7 or 8 at or near the edge of the support, and to which circuit connections may be made.

In FIGURE 2 there is illustrated a common electrode having a substantially radially arranged body 9 and a plurality of circumferentially arranged, spaced branches 10, 11 etc. Additional electrodes 12, 13 etc. are provided, having circumferentially arranged branches lying between the branches 10, 11 etc. of the first mentioned electrode. A coating of light-sensitive material 14 completes the photo cells. The electrodes 12, 13 etc. may be provided with contacts 15, 16 etc. near the edge of the support 17.

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The branches of the first mentioned electrode define the individual cells, which are adequately isolated thereby.

In FIGURE 3 a somewhat expanded arrangement is shown enabling the provision of two photo cell arrays in a confined space. Here on the base 18 a common electrode is provided having a radially arranged body 19 and circumferentially arranged branches 20, 21 etc. extending from both sides of the body. At each side of the body is provided a series of electrodes 22, 23 etc. and 24, 25 etc. coating with respective pairs of the branches as shown. Coatings of light-sensitive substance 26, 27 complete the two arrays. The common electrode has a contact element 28 adjacent the edge of the support; and the coating electrodes have similar contact elements 29, 30 etc.

For certain purposes hereinafter set forth, it is desirable that each photocell have three electrodes. One way of accomplishing this is shown in FIG. 4. One common electrode has a substantially radial body 31 and circumferentially arranged branches 32, 33 etc. Another common electrode has a substantially radially arranged body 34 and circumferentially arranged branches 35, 36 etc. The branches 35, 36 of the second common electrode cross the portion 31 of the first common electrode and must be kept out of electrical contact therewith. To this end the first common electrode has its substantially radial portion covered with a coating 37 of insulating substance prior to the imposition of the second common electrode. The coating electrodes 38, 39 etc. have branches lying respectively between a branch of the first and a branch of the second common electrode as illustrated. The individual cells are completed by the imposition of a light-sensitive layer 40 on the support 41; and each individual cell is defined by a branch of the first and an adjacent branch of the second common electrode. Contact elements may be provided as at 42, 43 and 44.

Yet another such arrangement is illustrated in FIG. 5. On one side of the array there is a common electrode having a substantially radially arranged body 45 and circumferentially arranged branches 46, 47 etc. At the opposite side of the array there is another common electrode having a substantially radially arranged body 48 and circumferentially arranged branches 49, 50 etc. The branches of the two common electrodes extend toward each other in intermeshing spaced relationship; and the coating electrodes consist in circumferentially arranged portions 51, 52 etc. These portions cross the body 45 of the first common electrode and are insulated therefrom by the layer 53. The photo cell array is completed by the layer 54 of light-sensitive substance.

In this figure, a second photo cell array is generally indicated at B coating with a first photo cell array A. These arrays may be thought of as for different voices, and there will therefore be cross connections between the coating electrodes of each. The second array does not need to be specifically described since it is substantially like the first; but the cross connections are indicated at 55, 56 etc., and will comprise a portion of the circuitry hereinabove mentioned. The common electrodes have contact members 57, 58, 59, and 60 on the base 61 and can be used in connection with switching means for voice selection. The coating electrodes of the several arrays are connected in series as indicated and are provided with contacts 62. The cross connections 55, 56 etc. can be at the same pitch level or at different pitch levels, as for example where it is desired to couple an 8 foot voice to a 4 foot voice or the like.

An exemplary arrangement for a photoelectric organ is illustrated diagrammatically and in an exploded fashion in FIG. 7. The arrangement comprises a light source 63 which will be provided with a reflector 64. More than one light source may be employed if desired. The light from the reflector first passes through a pitch disc 65. This disc will be rotated at a constant selected speed. It will bear circumferentially arranged pitch indicia, usually but not necessarily in the form of light slits or clear areas

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66 in an otherwise opaque ground. The pitch disc will be driven, and means for this purpose are diagrammatically illustrated in FIG. 7 as a pulley 67 and belt 68, though in actual practice it will usually be found preferable to attach a laminated armature to the periphery of the pitch disc and drive it by electromagnetic means as illustrated and described in the aforesaid United States patent to Jones, No. 2,576,759.

The voice disc 69 bears on its surface circumferentially arranged voice patterns 70. These patterns are repetitive circumferentially and are characterized by variations (either in width or in density) characteristic of the harmonic content of some particular desired voice. Since the voice disc is stationary, there is no point in continuing the voice representations 70 for any given timbre beyond an area overlying a particular photo cell array. In other words, the voice disc may be divided into segmental areas for different voices.

Finally the assembly comprises the support 71 containing a plurality of photo cell arrays designated in FIG. 7 at C, D and E, the general nature of which will be clear from the foregoing explanation. An arrangement is shown whereby the coating electrodes heretofore described act as the polarizing electrodes and are connected through individual switches 72, 73 etc. to a bus 74 containing a battery or other source of polarizing potential 75. This arrangement is used for note or frequency selection by the operator in accordance with the requirements of a musical composition, the switches 72, 73 being connected to the playing keys of the instrument. The several arrays of photocells C, D and E may be connected through a switch arrangement 76 to a bus 77 which in turn is connected to an amplifier and loud speaker system. Thus there has been shown in FIG. 7 the essentials of one form of photoelectric musical instrument providing for the playing of a plurality of notes in selective voices.

In each array in FIGS. 7 and 10 the coating of light-sensitive substance 78 can be arranged so as to be equal to or a multiple of the distance on centers of the light slits 66 in the several rows on the pitch disc or else the same effect can be secured by masking. The masking may be done by the voicing representations on the voice disc as will be readily understood. The pitch disc breaks up the incident light into traveling beams which scan the several voice representations. In this way the light incident on any one photo cell in an array will vary in accordance with a desired fundamental frequency and a preselected number and amplitude of harmonics related to the fundamental.

Other arrangements are possible. For example, as shown in FIG. 8 a photo cell array F on a fixed support 79 may be employed in connection with a stationary pitch disc 80 and a rotating voice disc 81. In this instance the voicing representations 82 on the voice disc will be circumferentially continuous; but the pitch disc may be divided up into segmental areas with the light slits differently spaced circumferentially in such segmental areas.

A still simpler construction is illustrated in FIGS. 6 and 9. This construction, in addition to the light source and reflector, employs a fixed disc or support 83 containing arrays of photo cells, and a moving voice disc 84. The voice disc has continuous circumferentially arranged wave form representations 85. In this form of structure the areas of light-sensitive material 86 are each arranged radially, and are so narrow in the circumferential direction that they have the effect of scanning the voice representations on the voice disc 84 so as to provide electrical vibrations characterized by a desired fundamental frequency and a harmonic content, the kind and amplitude of which is determined by the voice or wave form representations in the series 85. It is possible in this structure to multiply circumferentially the number of areas of light-sensitive material 86 in the various circumferential series so as to attain greater volume, the said areas being interspaced from each other a circumferential

distance equal to or a multiple of the length of individual wave form representations on the voice disc.

In FIG. 6 there is shown a three-electrode system comprising a common electrode having a substantially radially arranged body 87 and circumferentially arranged branches 88, 89 etc., the branches contacting the areas of light-sensitive material near one end in each row. Another electrode such as 90 or 91 is arranged to contact the other ends of the areas of light-sensitive material as shown, while a third electrode such as 92 or 93 traverses the centers of these areas. What is in effect a two-electrode system is shown in FIG. 9 where a common electrode has a radially arranged body 94 and branches 95, 96 etc. The centers of the various areas of light-sensitive material in each circumferential band is traversed by a separate electrode such as 97 or 98.

The structure just described has the advantage of mechanical simplicity; but it will be evident that a continuous circumferential voicing representation must be provided for each voice in each frequency throughout the range of the instrument. If the instrument has a wide range of frequencies and a wide range of voices, this may lead to the use of large voice discs and photo cell assemblies or to a multiplication of these elements.

By means such as have been disclosed, however, it is readily possible selectively to generate electrical vibrations which are characterized by a fundamental frequency and a high content of harmonics of wide range and amplitude, and then secure different voices by selective filtration of the vibrations in ways known to the art. Thus a comparatively simple mechanical photoelectric assembly may be employed which can be, but is not necessarily the structure of FIGS. 6 and 9. In all of the structures thus far described the nature of the vibrations produced as to their harmonic content will of course be determined by the voicing representations on the voice disc. An analytic type instrument in which voice differentiation is secured through selective filtration or by means of formant circuits, can be arranged to generate but a single type of wave form rich in the harmonics adjacent the fundamental; but it can also be arranged to generate two or more types of wave form suitable for selective filtration with or without combination. Thus a wave form may be generated which is rich in the even order harmonics and weak in the odd order, and another wave form may be generated which is rich in the odd order harmonics, the latter being especially adapted for modification to secure woodwind tones. The selection of different voices may be accomplished in all of the modifications herein discussed either by appropriate circuitry containing switches, or by door-like shutters (such as those shown in the Jordan Patent 2,506,599 noted above) adapted selectively to cover and uncover whole arrays of photo cells for different voices. But it will have been noted that in the structures herein taught, note selection is accomplished by circuitry including key switches, thus eliminating the problem of individual note shutters and their mechanical connections to playing keys.

The pitch discs and voice discs employed are preferably though not necessarily reproduced photographically from master negatives. The master negatives may be made by methods and apparatus taught in the copending application of Jones, Serial No. 135,912, filed December 30, 1949, now Patent No. 2,839,960, issued June 24, 1958, and entitled, Electronic Synchronizing System for Producing Pitch Discs and the Like. As has been understood, the various fundamentals of the notes of the tempered scale can be closely approximated by series of whole numbers which are not excessively large. In other words, it is possible to divide any given circle into a series of equal divisions which when the circle is rotated at a fixed speed will give a desired fundamental frequency, and to do this throughout the range of the tempered scale with entire auditory satisfaction both as to the relationship of the fundamental frequencies and the relationship

of the harmonic frequencies pertaining thereto. The principle applies to the formatoin of voice discs as well as pitch discs. In a voice disc each circular division will contain a wave form representation, i.e. variations either in width or density representative of the harmonic content of the desired voice.

Voices can be attained in the practice of the invention by configuring the individual photo cells (e.g. varying the effective width of the areas of light-sensitive substance between spaced electrodes which are themselves configured for the purpose). In this case a rotating pitch disc may be used to scan the photo cells in each array, and the voice disc as such may be omitted.

However, more accurate control can be accomplished by the use of voice discs as set forth above. The preferred form of electric organ employing the principles of this invention, is that shown in FIG. 7, employing a rotating pitch disc, a fixed voice disc and a fixed support or supports containing the various photo cell arrays. Very beautiful, individual voices can be secured in such a system from carefully made voice discs; the voice discs may be divided up into segments each producing a different voice at the same frequency; the arrays of photo cells may be similarly divided and placed to coact with the voicing representations on the voice disc; cross-coupling means may be provided on the support or supports for the photo cell arrays; and an instrument of great flexibility and range may be produced with a single mechanical assembly such as is diagrammed in FIG. 7 without mechanical connection to the keys and without an uneconomical complexity of external circuitry. An arrangement of photo cell arrays for the swell manual and pedal clavier of such an instrument is diagrammed in FIG. 14. The photo cell arrays are indicated at G, H, I, etc. It is believed that the figure will be clear to the skilled worker in the light of the legends thereon. He will understand that another assembly of arrays of photo cells can be provided for the notes and voices of the great manual in a two-manual instrument. It is possible, of course, to provide any given instrument with a plurality of the mechanical assemblies diagrammed in FIG. 7 for the same or different manuals; and where a plurality of such assemblies is provided, it is possible to attain choral effects by slightly detuning them.

The selection of voices in instruments of this class may be accomplished in various ways. As indicated above, door-like shutters may be provided for separate photo cell arrays. Separate light sources could be provided for illuminating the wave patterns of each separate voice. Where cross coupling is not practiced adjacent the photo cell arrays, their leads could be brought through a plurality of switches beneath each key to separate headers, the outputs of which could be selected through appropriate switches. But it is simpler to provide for the selection of voices through one or more switch means for each photo cell array as hereinafter illustrated.

In a system in which photo-voltaic cells are employed note selection may be accomplished through key switches alone. Where the photo cells are of the photo-resistive type, either note selection or voice selection may be accomplished through switches controlling the polarization of the individual cells. FIG. 11 is a partial circuit diagram showing portions of two arrays of photo cells indicated at J and K. These cells are of the two-electrode type heretofore described, for example, in connection with FIGS. 1, 2 and 3. A source of polarizing potential is shown at 99, one side of which is grounded as at 100 and the other of which is connected to a bus 101. A branch lead from this bus is connected to the common electrode of the array J through a transient-reducing resistor 102 and a voice selector switch 103 (normally actuated by a stop tab in the instrument). A transient-reducing and by-pass capacitor 104 may be connected between the switch and ground. Another branch lead from the bus

101 is connected to the common electrode of the array K through a resistor 105 and a voice selector switch 106. This circuit may also have a similar capacitor 107. The coacting electrodes of the photo cell array are shown as cross-coupled and as having leads 108 and 109. These leads are connected to a bus 110 respectively through switches 111 and 112. These switches may be thought of as connected with the playing keys of the instrument, and are preferably though not necessarily of the "gradual-contact" type, such as those described in U.S. Patent 2,215,124 to Kock and Jordan. Such switches eliminate an unpleasantly abrupt onset of the tones. Each of the leads 108 and 109 may contain a capacitor 113 or 114 bypassed to ground by resistances 115 and 116 or 117 and 118. The purpose of these networks is to filter out the direct current component of the signal, since the alternating current component is that desired for amplification. The bus 110 is connected to an amplifier 119 which in turn is connected to a loud speaker system 120. If desired, filter means 121 may be connected in the bus 110 for tone modification.

Photo cell arrays in which the individual cells comprise three electrodes have hereinabove been described as for example in connection with FIGS. 4, 5, 6 and 10. Such cells have a distinct advantage in that they are adapted to be connected to a push-pull amplifier or its equivalent in such a way as to cancel the direct current signal components, rendering unnecessary the use of filter networks for the purpose as described above, and making possible a different keying system as will later be described. FIG. 12 shows partially and diagrammatically a circuit arrangement employing such cells, while FIG. 10 shows one arrangement of pitch disc and voice disc in connection therewith. In this modification polarization is accomplished through the key switches. Two arrays of photo cells are partially indicated at L and M. As before, these may be arrays for different voice timbres or for voices of different frequencies or footage values, or both. A source of polarizing potential 122 having one side grounded as at 123 is connected to a bus 124. A branch from this bus passes through a key switch 125 and a transient-reducing resistor 126 to the coacting or intermediate electrodes of interconnected photo cells of each array. Another branch passes through a key switch 127 and resistor 128 to another interconnected group of photo cells, and so on. The common electrodes of the array M are brought out and connected through a gang potentiometer arrangement 129 to the leads of a balanced amplifier 130 as shown. By using wave forms on the voice disc that are of opposite polarity for the two halves of the three electrode photo cells as shown at 70 and 70a in FIG. 10, the signals at the two inputs of the amplifier add whereas the D.-C. or transient components cancel. Instead of a vacuum tube push-pull or difference amplifier, it is sufficient to use a center-tapped transformer the secondary of which is connected to an amplifier whose first stages at least are single-ended. All of these are intended to be comprised in the term "balanced amplifier." A transformer has the advantage of having less input resistance to D.-C., causing less trouble with spurious polarizing voltages being built up across those photo cells which are not used at a particular moment. Similarly, the two common electrodes of the array L may be connected to the same leads through a gang potentiometer 131. The amplifier is connected to a loud speaker system 132. The key switches again may be but need not be of the gradual contact type; and the key switch leads may be provided with transient-reducing networks 133 and 134.

The circuitry of FIGS. 11 and 12 will provide an instrument giving sustained or organ-type tones. Nevertheless, with suitable mechanisms connected with the key switches, it is possible to produce tones of a percussive character, for example, tones of which the initial loudness is dependent upon the key velocity, the tones decaying at a gradual rate. Various mechanisms for this pur-

pose are known in the art and reference is made here to U.S. Patent 2,095,707 to Kucher, to Patent 2,482,548 to Kerkhof, and to Patent 2,302,457 to Midgley et al.

In FIG. 13 there is illustrated a system for the production of percussive, transient or similar type tones, this being a system in which the polarizing voltage of the photoelectric cells is applied through key switches, while the tone signals are selected through stop switches. A source of polarizing potential 135 has two leads 136 and 137. A key switch is indicated at 138 provided with a resistor 139. The switch has been shown as a single-pole, double-throw switch. This may be connected with a playing key in various fashions as hereinafter explained. The blade of the switch is connected through the resistor 139 to a lead 140 to the coacting terminal of a photo cell 141 in an array N. Other arrays are indicated in the figure at O and P, and these may be cross coupled to the first as shown. The common electrodes of the photo cells in the array N are connected through a double switch pole, double-throw 142 or through a potentiometer to the leads of a push-pull amplifier 143 feeding a loud speaker 144.

Between the lead 140 and the lead 136 is connected a capacitor 145 bypassed by a resistance 146. During the time the switch 138 makes contact with the lead 137 a charge is applied to the capacitor 145. When this contact is broken, the capacitor 145 is disconnected from the source 135 and discharges, polarizing the photo-cell 141 with a potential which is not constant but declines at the rate of discharge of the capacitor, producing a percussive-type tone envelope. The rate of decay or decline of the polarizing potential can be controlled by the size of the capacitor and the value of the resistor 146.

The switch 138 may be actuated by the key in various ways. If, upon depression of the key, the switch 138 makes contact with the lead 137 and retains that contact until the key is released, the tone produced will remain at constant loudness until the key is released, at which time an exponential decay will occur. The effect will be that of organ tones excepting that if the keys are played staccato, the exponential decay will become apparent, giving a harp-like effect, or effects similar to plucked strings, struck bars, etc. If, on the other hand, upon depression of the key the switch makes momentary contact with the lead 137 and then breaks this contact, the exponential decay will occur immediately upon the full depression of the key, giving piano-like effects. If a mechanism is employed to cause the duration of the contact effected by the switch 138 with the lead 137 to be roughly proportional to the key velocity, then the loudness of the tone is under the control of the performer, or a circuit as in the Kerkhof patent could be used to control loudness.

If, upon depression of the key, the switch 138 first effects contact with the lead 137 and then with the lead 136 when the key is released, the effect will be that of causing the tone to die out more rapidly, simulating the action of the damper in a piano.

Modifications may be made in our invention without departing from the spirit thereof. Having thus described our invention in certain exemplary embodiments, what we claim as new and desire to secure by Letters Patent is:

1. In a photocell array, an insulative support, a common electrode on said support, said common electrode having spaced, substantially parallel portions, intermediate electrode means lying respectively between said parallel portions of said common electrode, and a coating of photosensitive material interconnecting said several electrodes, said electrodes being in the form of conductive coatings on said support, said coating of photosensitive material being confined to an area lying between the outer ends of the substantially parallel portions of said common electrode and the oppositely directed ends of said intermediate electrode means.

2. In a photocell array, an insulative support, a com-

mon electrode on said support comprising a bus portion extending in one direction and a plurality of substantially parallel branches extending in another direction, intermediate electrodes having portions lying respectively between said branches, a coating of photosensitive material interconnecting said branches and portions, said electrodes being in the form of conductive coatings on said support, said coating of photosensitive material being confined to an area lying between the outer ends of said branches and the oppositely directed ends of said intermediate electrodes, and means adjacent a margin of said support for making electrical contact with said common and intermediate electrodes.

3. The structure claimed in claim 2, wherein branches extend oppositely from each side of said bus portion, there being intermediate electrode portions located between adjacent branches on both sides of said bus portion, whereby two arrays of photocells are provided.

4. The structure claimed in claim 2, in which said insulative support is a disc, and in which said branches extend in the circumferential direction of said disc.

5. In a photocell array, an insulative support, and a plurality of photocell assemblies in contiguity on said support forming an array, each of said photocell assemblies comprising three spaced and substantially parallel electrodes, at least one electrode of each assembly serving in common as an electrode of an adjacent assembly in the array, and a coating of photo-sensitive material interconnecting said several electrodes, and confined to an area between the ends of said electrodes.

6. In a photocell array, an insulative support, a pair of common electrodes on said support, each common electrode having a bus portion extending in one direction and a plurality of substantially parallel branch portions extending in another direction, the branch portions of the common electrodes lying in spaced, interdigitating relationship, intermediate electrodes lying respectively between adjacent branches of the common electrodes and a coating of photosensitive material interconnecting said branches and intermediate electrodes, said coating of photosensitive material being confined wholly to a common area lying inside the ends of said branch portions and the ends of said intermediate electrodes, said electrodes being in the form of conductive coatings on said support.

7. The structure claimed in claim 6, in which certain portions of said electrodes cross each other on said support, with the interposition of an insulative layer between the crossing portions of said electrodes to prevent electrical contact therebetween.

8. In a photocell array, an insulative support in the form of a disc, and a plurality of photocell arrays arranged substantially radially on said disc, each such array comprising at least one common electrode having substantially radially extending bus portions and substantially circumferentially extending parallel branches, intermediate electrodes on said support having portions lying between the said branches, coatings of photosensitive material interconnecting the branches and intermediate electrodes of each array, said coatings being confined to an area lying inside the ends of said branches and intermediate electrodes, and connections on said support between the intermediate electrodes of the several arrays.

9. The structure claimed in claim 8, wherein the last mentioned connections are effected between intermediate electrode portions at different radial positions on said disc.

10. The structure claimed in claim 8, wherein each array comprises two common electrodes with interdigitating branches, wherein the electrodes and connections are in the form of conductive coatings on said support, and wherein certain portions of said electrodes cross each other on said support, with the interposition of an insulative layer between the crossing portions of said electrodes to prevent electrical contact therebetween.

11. The method of making a photocell array on an insulative support comprising producing on said support a common electrode in the form of a conductive coating thereon, said common electrode having a bus portion extending in one direction and a plurality of substantially parallel branches extending in another direction, forming on said support intermediate electrodes having portions lying respectively between said branches, and depositing on said branches and said intermediate electrode portions a coating of photosensitive material so as to interconnect the same, while confining the said coating of photosensitive material to an area lying wholly between the ends of said parallel branches and the ends of said intermediate electrodes.

12. The method claimed in claim 11, in which said photosensitive material is a material the resistivity of which varies upon the impingement of light thereon.

13. A process of making a photocell array which comprises producing on an insulative support a plurality of electrodes in the form of conductive coatings thereon, said electrodes having portions arranged in substantially parallel interdigitating relationship, and depositing on said support a coating of photosensitive material interconnecting said substantially parallel portions, the said structure being one in which electrode portions cross each other, and the said process being characterized by the initial formation of certain of said electrodes, the coating of portions thereon where other elements will cross them with an insulative layer, followed by the formation of the remainder of said electrodes.

14. In a photoelectric musical instrument having a light source, playing keys, and an electro-acoustic translating system, a moving member having patterns thereon respectively determinative of at least the pitch of the tones to be produced, a stationary member having disposed thereon an array of photocells comprising one for each of certain patterns, said photocells being respectively aligned with patterns on said moving member, and circuit means connecting said photocells to said electro-acoustic system, and playing key operated means connected to said photocells determinative of which of said photocells shall be active to transmit tone signals via said circuit means to said electro-acoustic translating system, in which the said array of photocells on said stationary member comprises a series of electrodes in the form of metallic coatings thereon, said electrodes having coacting portions, and a coating of photosensitive material on said stationary member interconnecting said coacting portions, said coating being confined to an area lying wholly between the ends of said electrodes.

15. The structure claimed in claim 14, in which the said photocells are of the variable impedance type requiring polarization, and in which the playing key operated means act to polarize individual photocells.

16. The structure claimed in claim 15, including means in connection with said playing key operated means for providing a desired rate of application and withdrawal of polarization to the individual photocells.

17. In a photoelectric musical instrument having a light source, playing keys, and an electro-acoustic translating system, a moving member having patterns thereon respectively determinative of at least the pitch of the tones to be produced, a stationary member having disposed thereon an array of photocells comprising one for each of certain patterns, said photocells being respectively aligned with patterns on said moving member, circuit means connecting said photocells to said electro-acoustic system, and playing key operated means connected to said photocells determinative of which of said photocells shall be active to transmit tone signals via said circuit means to said electro-acoustic translating system, the said array of photocells comprising an insulative support, a common electrode on said support, said common electrode having spaced substantially parallel portions, intermediate electrode means lying respectively between said parallel

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portions of said common electrode, and a coating of photosensitive material interconnecting said several electrodes, said coating of photosensitive material being confined to an area lying wholly between the ends of said parallel portions of said common electrode and the oppositely directed ends of said intermediate electrode means, said electrodes being in the form of conductive coatings on said support.

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