

Feb. 19, 1935.

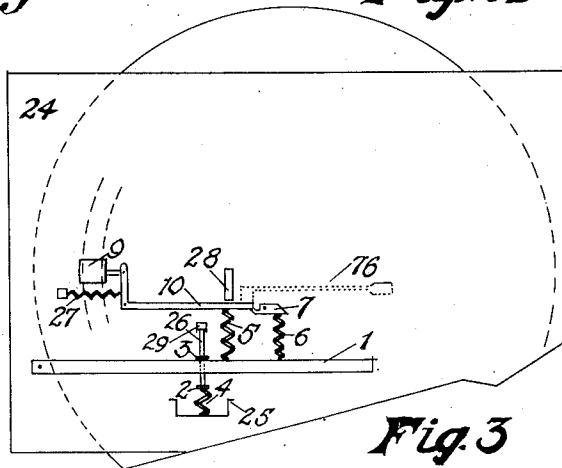
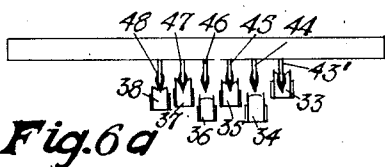
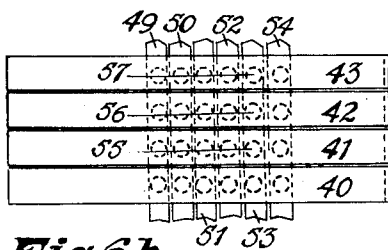
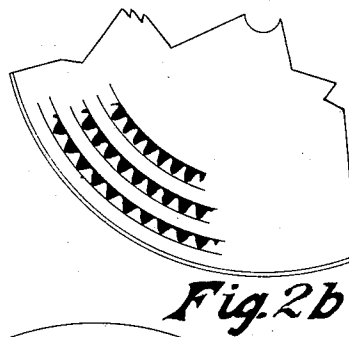
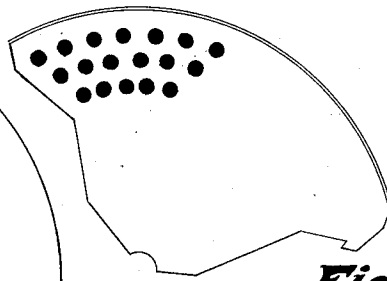
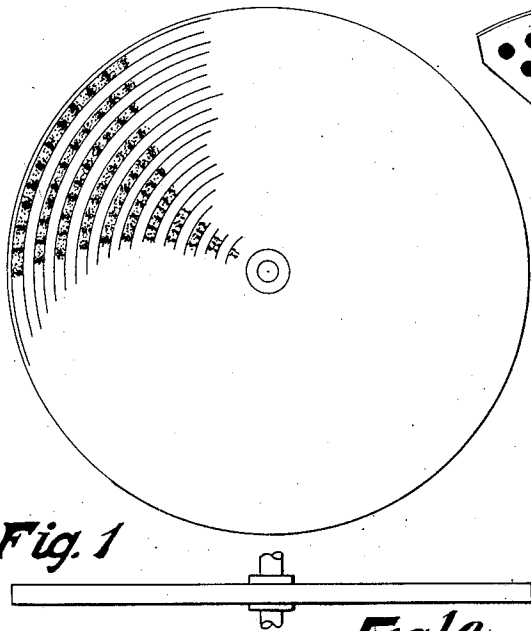
R. H. RANGER

1,991,522

APPARATUS FOR PRODUCING MUSICAL SOUNDS

Filed March 30, 1931

3 Sheets-Sheet 1



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APPARATUS FOR PRODUCING MUSICAL SOUNDS

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Fig. 7

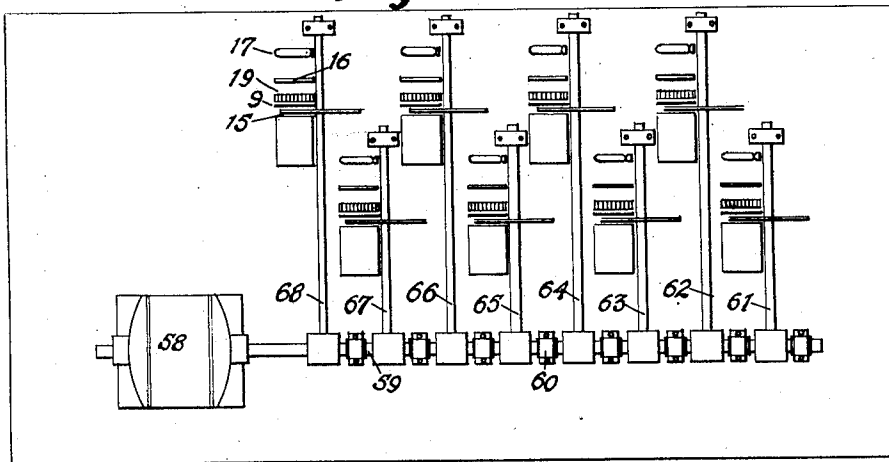


Fig. 8

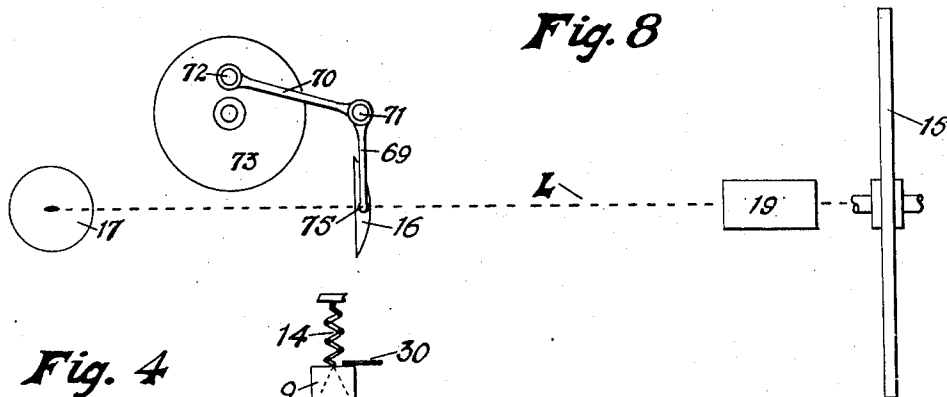
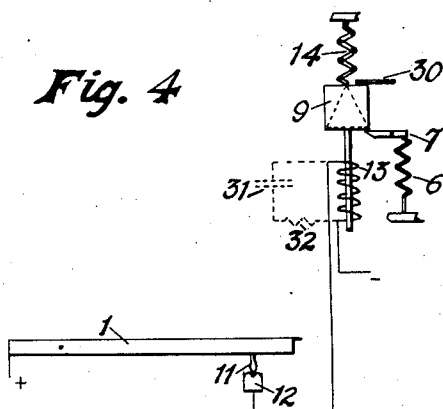


Fig. 4



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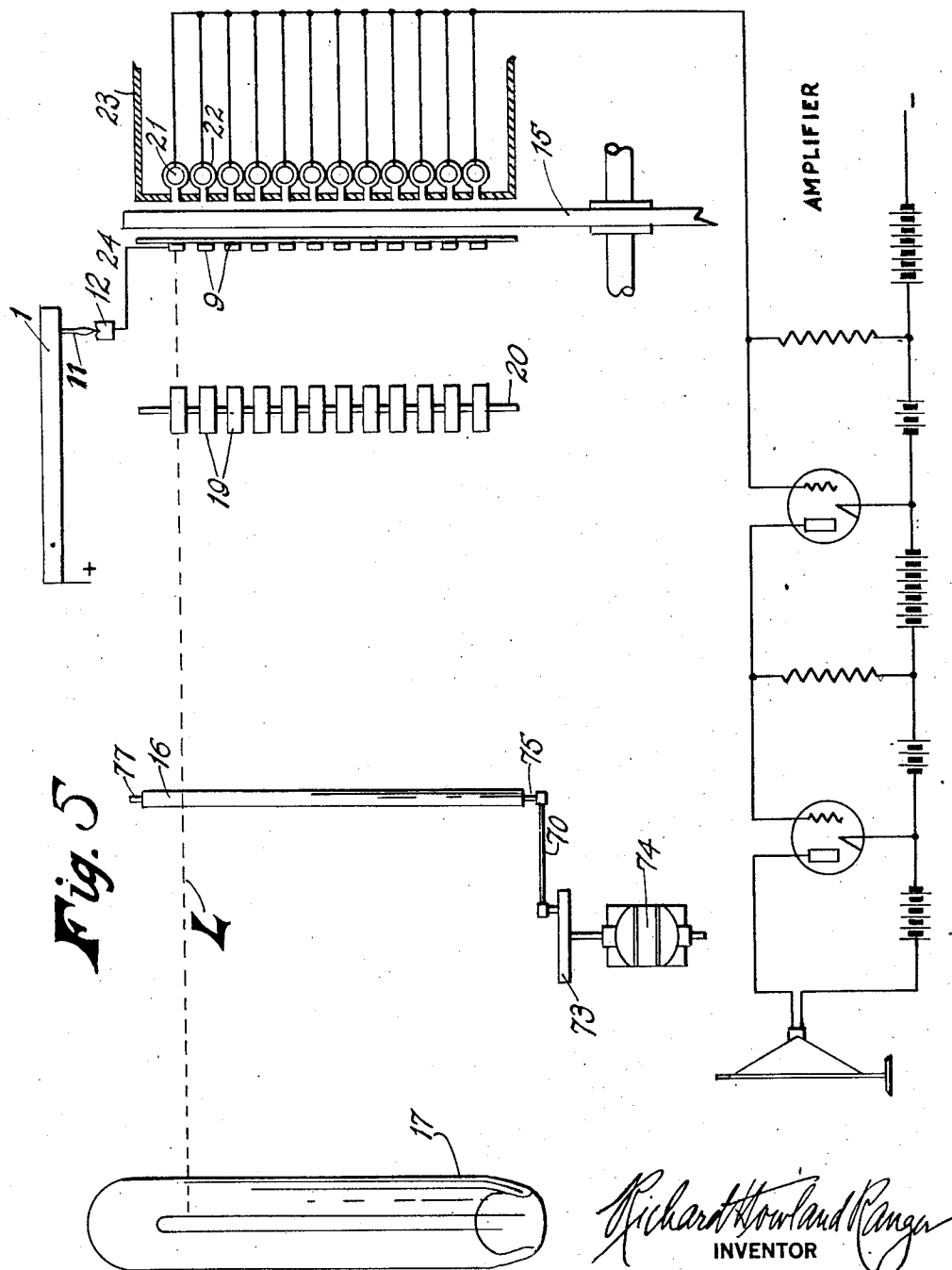
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APPARATUS FOR PRODUCING MUSICAL SOUNDS

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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

1,991,522

APPARATUS FOR PRODUCING MUSICAL
SOUNDS

Richard Howland Ranger, Newark, N. J.

Application March 30, 1931, Serial No. 526,269

12 Claims. (Cl. 84—1)

My invention relates to a system for the production of electrical oscillations of sinusoidal characteristics and their metamorphosis at the will of a performer into musical sounds of any desired volume and timbre.

It is the general object of my invention to provide a musical instrument wherein a plurality of tone sources is employed for each of the plurality of notes comprising the musical scale. Each tone source produces a tone of sinusoidal or undistorted quality, and each note is formed by combining the tones corresponding to its fundamental or first partial and the related harmonics or upper partial tones in the proper proportion to give a desired timbre or musical quality. The compounded notes are then reproduced by loud speakers.

My Patent No. 1,901,985 granted March 21, 1933, has a similar object, but the present invention attains it in different fashion. Sacrificing some flexibility, it is much less expensive to construct, requires far less space, and is much better adapted to use by a performer unskilled in the electrical arts than my previous invention. It is not to be assumed, however, that the present invention differs from that of my former application merely in size and complexity: results are attained by totally different means, embodying numerous new and useful features.

A partial object of my invention is to provide a musical instrument wherein all primary tones are produced by a single rotating machine of simple, rugged construction, driven by a single speed-controlled electric motor. Such a system is most reliable (since the control system may reasonably be quite elaborate, and since variations in pitch between notes are impossible), cheap to construct, and easy to change in pitch to meet the requirements of voices or other instruments (since the temperament cannot alter). To accomplish this object, I employ light-sensitive electric cells as my sources of tone energy and rotating disks as the means of interrupting this energy sinusoidally.

It is a further object of my invention to reduce the number of photo-electric cells required in such an instrument as much as possible by providing a system wherein one photo-electric cell can act as the source of a fundamental tone and of the harmonics of a plurality of other fundamental tones at the same time, without interference between the various composite notes, and without distortion in the quality of any of them.

Another object of my invention is to provide a keyboard musical instrument using as its source

of tone a light-sensitive cell or cells acted upon by periodically interrupted light beams, wherein the amplitude of each note as caused to speak is dependent on the force with which the performer strikes or depresses the corresponding key, in contradistinction to instruments in which the keys merely trigger the tones, overall volume being regulated by a pedal or some other means apart from the keys. This object I achieve by using shutters to vary the intensity of the light beams corresponding to each fundamental tone produced by the instrument in accordance with the keying technique of the performer.

Photo-electrical musical instruments known to the art prior to my invention employed shutters in similar fashion to key the input to light-sensitive cells, but these shutters were so arranged that the quantity of light admitted to each cell, and thus the volume of tone output of the cell, was proportional to the depth to which the corresponding key was depressed. Such a system is very difficult to operate satisfactorily, as ordinary amateur technique is not equal to regulation of the depth of key depression on each note to the nicety required. Furthermore, the performer's speed in passage work is necessarily restricted, and the wavering audible effect of gradual increase of volume with key depression becomes most objectionable upon continued hearing.

My invention overcomes this defect by storing up keying energy during a portion of the manual keying action. When the key has been depressed to a predetermined depth it triggers this stored-up energy, snapping the shutter of the keyed tone at once to the proper position for a predetermined volume. Further key depression beyond this point will produce a proportionate increase in volume, but must overcome a relatively large opposing force.

A further concern of my invention is to provide a noiseless system of direct keying for an electrical musical instrument. Abrupt changes of current at the key contacts are not possible in the system described in this specification, and consequently objectionable keying noises are prevented.

Additional objects of my invention are to provide an electrical musical instrument wherein the musical quality or timbre of the entire keyboard, or of any desired portion of it, is set by a simple mechanical or electrical control system susceptible to control by a single manual operation such as drawing a stop or tilting a tablet; and to provide an electrical musical instrument

wherein a conventional and pleasing tremolo may be applied to any or all tones by a simple electrical means. By a conventional tremolo I mean a periodic fluctuation of the frequency of the note being played. A periodic fluctuation of the intensity of the note will also give a tremolo effect, but not nearly as pleasing a one as the conventional tremolo.

To illustrate my attainment of the above mentioned objectives, to bring out further advantages of my invention, and to clarify this specification in general, I have included drawings as follows:

Fig. 1 is a representation of the light-interrupting disk used in my invention, carrying screen tracks for twelve photo-electric cells. Fig. 1a is a view of the disk of Fig. 1, taken at right angles to its axis of rotation. Figs. 2a and 2b show alternative forms of screen tracks. Fig. 3 illustrates a mechanically operated shutter embodying my principles of operation, and Fig. 4 shows the same in electrical form. Fig. 5 is a schematic representation of the optical system and electrical connections for one octave of the instrument. In Figs. 6a and 6b the keying system is illustrated for several notes, Fig. 6a being the elevation and Fig. 6b the plan view; Fig. 7 depicts a complete tone producing unit and Fig. 8 illustrates the operation of the tremolo.

All the fundamental tones comprising one octave are obtained from a single disk of the form shown in Fig. 1. On the face of this disk are photographed or otherwise inscribed twelve concentric paths of constant width, whereon the intensity of shading varies sinusoidally from black to white periodically around the length of the path. The variable width method well-known in the talking picture art may also be applied to the inscribing of these paths. The number of complete cycles of shading contained in a path is a measure of the frequency of the electric waves which can be generated by revolving the path at a given speed between a photo-electric cell and a source of light, and therefore is also a measure of the pitch of the audible tone given out by a loud speaker or electrical reproducer energized by such an electric wave. Only a few of the cycles of shading contained in each path are shown in Fig. 1.

To make the frequencies generated by the 12 paths equal the 12 semitones of the well-tempered octave, each path would require $2\frac{1}{2}$ times the number of cycles contained in the path next lowest in frequency. Since the factor $2\frac{1}{2}$ is not a whole number it is necessary to compromise in some manner, and my method of compromise is to use a large number of cycles N in the lowest frequency path, and to use the nearest whole number of equally spaced cycles to the theoretical values of the other paths. The accuracy of the frequencies generated will depend upon the factor N ; e. g., for an accuracy of 0.10% N would equal 1000, as .1% of 1000 is 1, the smallest unit division corresponding to a cycle.

The light-chopping paths need not be of the type shown in Fig. 1. They may consist of equally spaced transparent holes in an opaque background, either circular, as shown in Fig. 2a, or sinusoidal in shape, as shown in Fig. 2b. The form of Fig. 2b corresponds to the variable width talking picture method mentioned above, and should be used in cases where an undistorted output is desired. In the following sections, it is assumed that the disk is according to Fig. 1.

As shown in Fig. 5, the light from a long and

narrow source (such as an incandescent lamp of the form shown at 17) passes through a cylindrical lens 16 and then through twelve condenser lenses 19, mounted in a light baffle 20, so that a concentrated beam of light is directed on each of the twelve sound tracks of the chopper disk 15, and through these tracks to each of the twelve photo-electric cells 21. These photo-cells are mounted in light shields 22, and for greater protection are enclosed in a box 23.

Between the condenser lenses 19 and the disk 15 is mounted a set of shutters 9 and a light stop 24. The shutters 9 regulate the amount of light input to each photo-cell, and consequently the intensity of tone derived from each photo-cell, when suitably amplified and reproduced by a loud speaker. As mentioned above, when the opening of the shutter is proportional to the amount of key depression; i. e., when there is a direct mechanical connection between the key and the shutter, the amplitudes of successive notes are seldom equal, and there is a monotonous crescendo effect as each key is depressed. I overcome this in my invention as follows:

Referring to Fig. 3, when the key is at rest, the bell-crank 10 is held against the stop 28 by spring 27, latch 7, and spring 6, and the key 1, due to the action of spring 5, is against the stop 3, which is mounted on the rod 26, passing through key 1. All these springs are fairly weak, so that a light touch is sufficient to depress key 1 to stop 2. When this is done, however, spring 5, due to its great leverage, builds up a great enough force to overcome the combined forces of springs 6 and 27, so that as key 1 reaches stop 2, the latch 7 releases, and bell-crank 10 flies down, snapping shutter 9 open to about $\frac{2}{3}$ of its opening for maximum amplitude. The motion of key 1 has also brought a catch 29 into position to make contact with the bell-crank 10 in its new position in such a fashion that a rigid connection between key 1 and bell-crank 10 is established for further depression of the key. Such further depression controls further increase of volume in the note being played but must be made against the heavy compressive resistance of spring 4. When the shutter is open to its fullest extent, key 1 strikes stop 25. When key 1 is released spring 27 pulls shutter, key, and bell-crank back until key 1 approaches stop 3, whereupon catch 29 releases and the bell-crank flies back against stop 28, resetting the latch 7.

Thus when any key in the instrument is struck or depressed, the appropriate note is reproduced at a set minimum intensity which it attains at once, and the performer has at his command an increase in intensity according to his manual technique. The minimum intensity of the notes may also be under the control of the performer, to fit the requirements of the musical passage he desires to interpret—I provide a pedal-operated potentiometer control on the last stage of the photocell amplifier, similar to the well-known volume control used on broadcast radio receiving sets, for this purpose.

Using the shutter mechanism described above, I am able to adapt my invention so that its action will simulate that of numerous instruments. A simple dashpot attached to the bell-crank 10, for instance, giving a slow return to the shutter after the key has been struck, makes the action almost exactly that of a piano. Similarly, an arm and weight such as is shown (dotted) at 76 in Fig. 3 may be attached to bell-crank 10, causing it to oscillate rapidly about its set position

of minimum tone intensity and producing an effect very like that of a vibraphone.

The apparatus shown in Fig. 3 serves well to illustrate the principles of light-shutter operation in my invention, and this form is amply suitable for simple instruments, but where greater flexibility is desired I find the electrically operated shutter of Fig. 4 much simpler, cheaper, and more reliable. The steps in its operation are without exception analogous to those in the operation of the mechanical shutter.

Key 1 is shown with one pair of keying contacts 11 and 12. This contact device is of a special and improved form, and is fully disclosed in a co-pending application for Letters Patent. It consists of a bakelite conducting member 11, coated with graphite, and a cup 12 containing a highly conductive liquid such as mercury. The contact resistance of this device depends on the amount of surface area of contact 11 which is immersed in the mercury, and so the amount of keying current fed to the relay coil 13 rises regularly and continuously as the key 1 is depressed, the rate of current rise depending on the rate of key depression and the shape of member 11. No sparking or noise is possible at such a contact, and thus the need of delay circuits or other devices for preventing such noises from becoming audible is obviated.

The key and contacts, however, build up current in relay 13 rather gradually, so that it is again necessary to make some provision for the rapid opening of shutter 9. This I have done by a spring and latch arrangement similar to that of Fig. 3. Shutter 9 is held against stop 30 by spring 14 and latch 7 until sufficient magnetic force is exerted by relay 13 to trip latch 7. The shutter 9 then snaps down to a position where the force exerted by relay 13 is balanced by the force exerted by spring 14. It is advisable that a small degree of sliding friction be developed between the shutter and its guides, to prevent oscillation about the position of balance. The vibraphone effect mentioned above may be achieved by making the shutter rather heavy and its guides as nearly frictionless as possible, thus encouraging oscillations.

By the addition of an electrical condenser of high capacity 31 to the circuit of Fig. 4, in series with a resistance 32 and across the relay coil 13, I obtain a very satisfactory simulation of the action of a piano, since the leakage of charge from condenser 31 through coil 13 continues for a time after key 1 is released, and returns shutter 9 very slowly to its position of rest.

Thus far only the production of pure tones has been discussed. While they are valuable as a musical standard of comparison or for truing the pitch of singers or the like, they are generally too colorless for performance use. I have, therefore, adapted my invention so that five harmonics or partials may be added to the fundamental tones at will, and in any desired proportion. The performer is thus enabled to produce the characteristic tones of almost any string, brass, or woodwind instrument known to the art, as well as tones entirely new in quality.

Keys 40, 41, and 42 of Figs. 6a and 6b carry six contacts of the type illustrated in Fig. 4. The graphite contact members 43', 44, 45, 46, 47, and 48 are rigidly fixed to key 40, in similar fashion to key contact member 11 of Fig. 4, but the fluid-cup members 33, 34, 35, 36, 37, and 38, instead of being fixed, are mounted on movable bars 49, 50, 51, 52, 53, and 54. These "harmonic bars",

as I shall designate them, traverse the keyboard from end to end, each of them carrying one of the mercury cups belonging to each key.

The six contacts on each key control the shutters for the light tracks producing the fundamental tone represented by the key, and its 1st, 2nd, 3rd, 4th, and 5th harmonics. Each harmonic bar carries the movable portion of all contacts controlling a single order of harmonic. For instance, bar 53 carries cup 34, controlling the first harmonic of the fundamental tone of key 40; cup 55, controlling the first harmonic of the fundamental tone of key 41; and cups 56 and 57, controlling the first harmonic of the fundamentals of keys 42 and 43 respectively.

With this construction, the percentage of any given harmonic which enters into any note as finally reproduced will depend on the height of the harmonic bar which corresponds to that harmonic, and thus the performer need only adjust the harmonic bar heights to regulate his quality of tone. A simple and practical way to provide such adjustments is by means of a rotatable dial and pointer for each harmonic bar, the dial being calibrated in percentage shutter aperture, and operating the bar through sprockets and pulleys. My invention is not limited to this arrangement, however, since other methods of control will readily suggest themselves to those skilled in the art.

Obviously, most of the shutters in the instrument will be controlled by a plurality of contacts. A given light track, for instance, may be used as the source of the fundamental tone of one key, the 2nd partial tone of another, the 3rd partial tone of still another, and so on. If several notes are played at once, a single keying relay may receive current from a plurality of sources, and be required to open the shutter which it controls in accordance with the sum of these currents. For this reason it is important that the aperture opened for the passage of light to a photo-cell be a linear function of the current passing through relay 13. My preferred method of achieving this is to use carefully designed solenoidal coils for the shutter-operating relays. The same result could be attained, however, by shaping the apertures in light-stop 20 to conform with the characteristics of the relay coils.

The machine supplying all the tones for the entire instrument is shown in Fig. 7. An electric motor 58 drives a shaft 59 supported at intervals by bearings 60. Geared to shaft 59 through reducing worms and worm gears are the driven shafts 61-68. Each of the driven shafts carries a disk 15, similar to the one shown in Fig. 1, and an optical system identical with that shown in Fig. 5; and each shaft is driven at twice the speed of the one next below it, and half the speed of the one next above it. The speeds are so chosen as to give any desired pitch; for example, suppose that it is desired to have the lowest note produced by shaft assembly 64 be the note "a" at International Pitch, or 440 c. p. s. Assuming also that the disk 15 carried on shaft 64 contains 1000 cycles in its shortest circular light track, the speed of the shaft must be

$$\frac{400 \times 60}{1000} = 26.40 \text{ R. P. M.}$$

and shaft 65 must turn at 13.2 R. P. M., shaft 63 at 52.8 R. P. M., and so on.

The machine of Fig. 7 will supply 8 full octaves, or 96 tones. The outputs of all the 96 photocells carried by such a machine may be run

to a single amplifier and loud speaker, as shown in Fig. 5. When a number of keys are played simultaneously in such a construction, however, there is danger that they will modulate each other, and my invention is thus best suited for use as a solo instrument. For a more expensive and more flexible instrument simple amplifiers and loud speakers could be supplied to the number of eight or ten, and the relay system described in my Patent No. 1,901,985, applied so that each note would be ensured of a separate amplifier and reproducer.

The operation of the tremolo effect in my invention may be understood from a consideration of Figs. 5 and 8. The cylindrical lens 16 is pivoted on two pins 75 and 77, allowing it to turn on an axis parallel to and at the same height as the light source 17. Rigidly attached to pin 75 is an arm 69, which in turn is pinned at 71 to an arm 70, which engages a pin 72 on driving wheel 73. Arms 69 and 70 are free to rotate about pin 71, and thus a rotation of wheel 73 produces a rocking motion of the lens 16 about the axis formed by the pivots 75 and 77. This rocking motion covers only a fraction of a degree—sufficient to deflect the light beams L a distance equal to the length of one cycle of the light paths on the disk 15.

If now the wheel 73 is driven by the motor 74, all 12 beams of light impinging on the disk 15 will oscillate back and forth in the direction of the disk's motion, and when the instrument is in operation the relative speed of the light and the light tracks will vary sinusoidally according to the speed of motor 74. Thus a periodic frequency fluctuation of the audible tones which exactly simulates the conventional musical tremolo is produced. By a simple rheostat control on motor 74, the speed of this tremolo may be made variable at the will of the performer.

What I claim as my invention, and desire to secure by Letters Patent, is:

1. In an electrical musical instrument, a source of light, means for directing a beam of light from said source on each of a plurality of light-sensitive cells, means for interrupting each of said beams in accordance with a musical tone, means for amplifying and making audible the electrical output of said light-sensitive cells, a shutter in the path of each of said beams, and means for operating said shutter including a key and means for inhibiting movement of the shutter until the key reaches a predetermined position whereupon said audible tone immediately attains a fixed percentage of its maximum volume and means whereby further depression of the key causes further increase in volume.

2. In an electrical musical instrument having as its source of tone a light-sensitive cell acted upon by a pulsating beam of light, a shutter in the path of said beam, means for supplying a continually increasing force tending to move said shutter out of the path of said beam, a detent for maintaining said shutter in the path of said beam until said force has reached a predetermined percentage of its maximum value, thereupon releasing said shutter to be moved under the influence of said force, and means for restoring said shutter to the path of said beam when said force is removed.

3. In an electrical musical instrument a light sensitive cell serving as a source of tone, means for producing a beam of light directed upon said cell, a shutter, a latch holding said shutter in the path of said beam, said shutter being designed to

be released upon the application of a predetermined force acting thereon, means engageable with said shutter upon release by said latch to hold the shutter in a position partially impeding the passage of said beam of light, keying means for applying a gradually increasing force to said shutter and operative to drop the latch when said force reaches said predetermined value and means for restoring said shutter to its original position when the force is discontinued.

4. In an instrument as described in claim 3 means for retarding the return of the shutter to its original position when the displacing force is discontinued.

5. In an instrument as described in claim 3 means for retarding the return of the shutter to its original position when the displacing force is discontinued and means for interrupting the dying tone produced when said shutter is returned to its original position.

6. In an electrical musical instrument a movable element for controlling a sound producing electric current operable to cause the current intensity to vary gradually with the position of the element, keying means for applying a gradually increasing force tending to move said element and means for resisting movement of the element until the force exceeds a predetermined minimum and then suddenly releasing the element to cause it to move to a predetermined position in response to said force, said element being movable beyond said predetermined position upon application of further increased force by said keying means.

7. In an electrical musical instrument an electrical circuit, means for controlling the intensity of current in said circuit variably over a substantial range including a movable element, keying means for applying a controllable force to move said element, latch means for resisting movement of said element until the force applied by the keying means reaches a predetermined minimum, a stop for limiting the movement of the element, said stop being movable to permit further movement of said element upon application of greater force through said keying means.

8. In an electrical musical instrument a tremolo producing mechanism comprising a movable element operable to control and vary the intensity of a sound producing electrical current, keying means for applying a gradually increasing force to move said element toward current increasing position, means operable to resist movement of said element until the increasing force reaches a predetermined minimum and means cooperating with said keying means for causing an oscillatory movement of said element.

9. In an electrical musical instrument a device for producing a tremolo effect comprising a light sensitive cell, a source of light, a moving control screen between the cell and light source, a lens in the path of the light and means for giving a rapid vibratory movement to said lens.

10. In an electrical musical instrument a device for producing a tremolo effect comprising a light sensitive cell, a source of light, a moving control screen between the cell and light source, and means for focussing a narrow band of light on said control screen and for giving said band of light an oscillatory movement in the direction of movement of said screen.

11. In an instrument as described in claim 3 means for retarding the return of the shutter to

its original position when the displacing force is discontinued, and means for interrupting the decaying tone produced when said shutter is returned to its original position.

12. In an electrical music system, a source of light focussed upon a plurality of light-sensitive cells, a rotating screen interrupting the light input to each of said light-sensitive cells in accordance with the frequency of the fundamental tone or a related partial tone of one of the notes of a musical scale, amplifying means for amplifying the generated frequencies for repro-

duction according to a predetermined schedule, and means for introducing a tremolo effect into the reproduced tones, comprising a lens whose optical axis coincides with the path of the light rays traveling between the said source, and the said light-sensitive cells, said lens being so oscillated at the desired tremolo frequency as to impart a regular wave motion to the said light rays in a plane tangent to the rotation of the said screen.

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