May 9, 1939. H. A. IAMS 2,157,824

PHOTOELECTRIC CELL OSCILLATION CIRCUIT

Original Filed Dec. 12, 1930

Fig. 1.

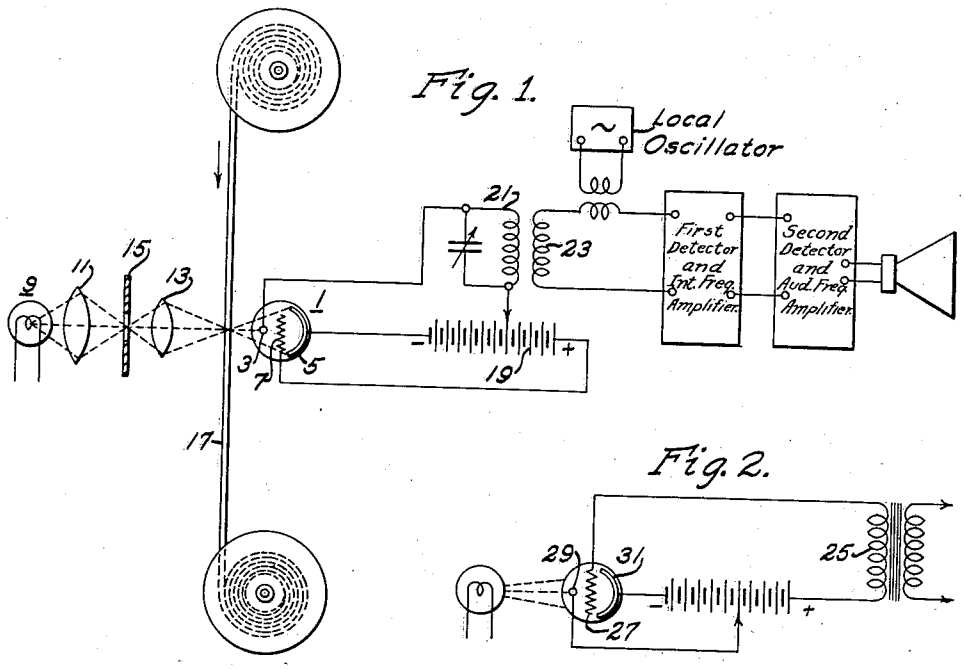


Fig. 2.

Fig. 3.

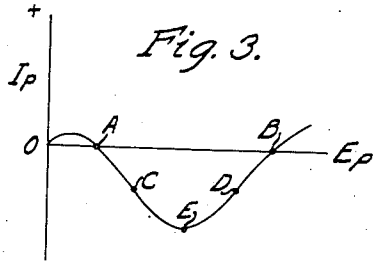


Fig. 4.

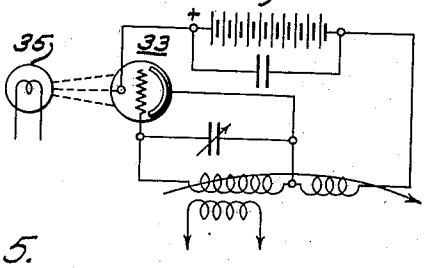
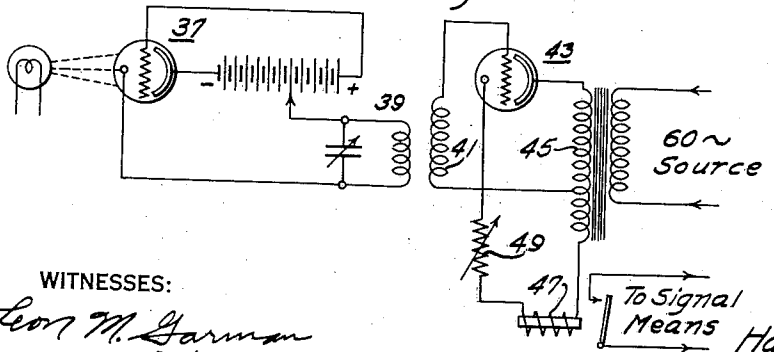


Fig. 5.



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PHOTOELECTRIC CELL OSCILLATION CIRCUIT

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Original application December 12, 1930, Serial No. 501,878. Divided and this application October 12, 1938, Serial No. 234,617

4 Claims. (Cl. 179—100.3)

My invention relates to photo-sensitive devices and their uses, more particularly to novel circuit arrangements embodying such devices whereby new and useful results may be obtained.

This application is a division of my application Serial No. 501,878, filed December 12, 1930, and assigned to the Westinghouse Electric & Manufacturing Company.

It is one object of my invention to provide means for increasing the sensitivity of a photocell or other analogous light-sensitive device.

Another object of my invention is to provide photo-cell means having amplification characteristics.

Another object of my invention is to provide an oscillation generator embodying a photo-sensitive device.

Another object of my invention is to provide means for expanding the field of usefulness of photo-sensitive devices.

Another object of my invention is to provide light-sensitive means capable of selectively generating alternating or direct current.

A photo-sensitive device, according to the prior art with which I am familiar, normally comprises an evacuated or a gas-filled tube containing a pair of electrodes, e. g., an anode and a cathode, the cathode being coated or impregnated with a photo-sensitive material. In certain cases, a third electrode has been added to photo-cells for the purpose of neutralizing or substantially reducing the capacity effect existing between the anode and the cathode.

According to my invention, I have provided novel means in the form of circuit arrangements embodying photo-sensitive devices whereby such photo-sensitive devices may be caused to operate or function to obtain new and useful results heretofore never associated with the use of such devices.

Prior uses of photo-sensitive devices in the art have been based primarily upon the characteristic of such devices to alter their effective internal resistances in response to light waves striking their cathodes and thus to correspondingly alter the currents in electric circuits of which such devices may be elements. When employed in this relation, the device finds a variety of applications in the arts.

I have found that, in addition to its use as a light-responsive resistor, a photo-sensitive device may be caused to function as an amplifier and as an oscillator, in a manner somewhat analogous to the operation of a three-element vacuum tube, at the same time increasing the sensitivity of the device, as compared with photo-sensitive devices as normally employed.

In order to employ a photo-sensitive device as an amplifier or oscillation generator, I provide a grid electrode in addition to the anode and the cathode, the grid, however, to function in a manner clearly distinguishable from its use in devices of the prior art which disclose grids in combination with an anode and cathode for neutralizing purposes.

Further description of my invention will be developed in connection with the accompanying drawing, wherein:

Figure 1 is a circuit diagram, partly in block form, illustrating one application of my invention wherein a photo-sensitive device is caused to function as an amplifier and oscillator,

Fig. 2 is a circuit diagram embodying a light-sensitive device according to my invention, wherein the amplifying characteristic of the photo-cell may be made more pronounced,

Fig. 3 is a diagram representing current changes in a photo-sensitive device when employed according to the teachings of my invention,

Fig. 4 is a circuit diagram illustrating an oscillator of the Hartley type employing a photo-sensitive device in lieu of a thermionic device, and

Fig. 5 is a circuit diagram illustrating a signalling system embodying my invention.

Referring more particularly to the drawing, the system disclosed in Fig. 1 is adaptable for use in the reproduction of speech and music from a talking movie film, as illustrated.

A photo-sensitive device 1, comprising three electrodes; an anode 3, a cathode 5, having a coating or impregnation of photo-sensitive material, and a grid 7; is so positioned as to receive a beam of energy from a source 9 directly against its photo-sensitive electrode 5. The beam from the source is directed through an optical condensing system comprising a plurality of condensing lenses 11 and 13 in combination with an opaque shield 15 slitted to provide a beam of sufficient dimensions and intensity for the purpose intended.

A motion-picture film 17, having a sound track thereon, is caused to pass between the optical condensing system and the photo-sensitive device, the optical system being so adjusted as to concentrate the beam of energy upon the sound track of the film only.

The energy, striking the cathode 5 of the photo-cell, will, accordingly, be modulated at audio fre-

quencies by reason of, and in accordance with, the light and the dark areas on the sound track of the film representing speech or music. By reason of the circuit arrangement disclosed and to be described, the modulated beam of energy will be transformed back, in corresponding sound waves, to render audible a duplication of the original program registered on the film.

Associated with the photo-sensitive device is a grid circuit comprising the grid 7, a source of high potential 19 and the cathode 5, and an anode circuit comprising the anode 3, and an oscillatory circuit 21 adjustably contacting the source of high potential 19 at an intermediate value. The tuned circuit is coupled through a transformer coupling to the input circuit 23 of a first detector to which is also coupled a local oscillator. The aforesaid transformer should be designed in accordance with principles well known in the radio art to transform energy efficiently at frequencies in the neighborhood of that to which the oscillatory circuit 21 is tuned. The output of the first detector is fed to an intermediate-frequency amplifier, then to a second detector and subsequently amplified, through audio-frequency amplifiers, to be impressed across the terminals of a loud speaker.

Except for the photo-sensitive device 1 and its associated circuits, the circuits represented in block form are analogous to those embodied in super-heterodyne receivers. However, while I have shown the photo-sensitive device in conjunction with a super-heterodyne amplifier, it may, with equal effectiveness, be employed in any suitable amplifying system.

The operation of the system described above may be explained as follows: Concentrating first of all on the photo-sensitive device and its associated grid and plate circuits, attention is directed to the fact that the potential on the grid is of a value materially higher than that on the anode. Light striking the cathode 5, which is photo-sensitive, will cause an emission of electrons toward the grid 7. Because of the high speed attained by the electrons, by reason of the high positive potential on the grid 7, a number of the electrons will shoot past the grid and will be attracted, because of positive plate potential, against the plate or anode 3, the effect of which will be to knock off from the anode a proportionately larger number of electrons which may be referred to as a secondary emission.

Under normal circumstances, the electrons emitted from the anode would immediately re-enter the electrode, but, by reason of the fact that the potential on the grid is of a higher positive value than that of the anode, a force of attraction will be exerted on the electrons, with the result that a flow of electrons will take place from the anode to the grid, thereby establishing a current, according to the popular view, from the grid to the anode. This secondary current may be made many times greater in magnitude than the current from the anode to the cathode which is due to the primary emission.

In Fig. 2, I have illustrated circuit connections whereby more pronounced amplifying characteristics may be obtained. The output circuit 25 of the photo-sensitive device, as here shown, comprises the grid circuit instead of the anode circuit, as described in connection with Fig. 1, wherein the amplifying characteristic is the result of obtaining a secondary emission of electrons from the anode of much greater magnitude than could normally be obtained as a primary emission from the cathode of the photo-sensitive device. Since the primary and secondary electron emissions are in opposite directions, and a grid 27 of higher positive potential than either the anode 29 or cathode 31 is interposed between the two electrodes, a current substantially equal to the sum of the resulting anode and cathode currents will find a return path through the grid circuit. Consequently, the output of the device through its grid circuit will be greater than that through either its anode or its cathode circuit and, accordingly, its amplifying characteristic will be of a greater degree.

In Fig. 3, I have illustrated, by means of a curve, the variations in plate current, as plotted against changes in the plate potential, the grid potential remaining substantially constant. When the anode voltage is low, few electrons from the cathode reach it and these will be traveling at low velocities only. The number of electrons knocked from the plate, therefore, will be smaller than that of the primary electrons arriving at the anode, so that the current in the anode circuit will be small but of a positive value. This is represented by the small hump in the curve in the positive direction for low values of plate potential. As the anode potential is increased, the electrons will arrive at the anode in greater numbers and at greater velocities. The secondary emission will, accordingly, be greater and will increase at a much more rapid rate than that of the primary electrons reaching the plate. The resultant plate current will, therefore, change direction and become negative. Further increases in plate potential will result in an increase in current in the negative direction until a maximum value is reached which will occur when the plate potential approaches that of the grid. This point of maximum value is represented at the lowermost bend of the curve. Additional increases in plate potential will cause the plate current to become less and less negative or more positive, since the grid, under the above conditions, will be unable to attract electrons knocked from the plate. The current will ultimately reverse direction and become positive again and will increase in value until saturation is reached.

It will thus be apparent that operation along a portion of the curve A—E will give a negative resistance effect, which, therefore, satisfies the condition for the generation of oscillatory current. It will also be apparent that, by fluctuating the plate potential about points A or B, an alternating current may be produced in the output circuit. If it is desired to produce a direct current in the output circuit, similar to that of a thermionic device, the photo-sensitive device may be operated at such point on the curve as is designated by C or D, whereby a modulated light beam, striking the cathode of the device, may be faithfully reproduced in the form of an electric current. This feature will find many applications in the art, such as in photo-phone work or the like, and possesses the advantage over the ordinary photo-cell in that the output energy in the plate circuit will be of greater value, being sufficient, in some cases, to permit of the elimination of a stage of amplification. If the grid circuit is employed as the output circuit, the advantage will be even more pronounced.

Referring back to Fig. 1, the photo-sensitive device, in the circuit arrangement illustrated, may be made to oscillate and, when in this state, its frequency will be determined by the oscillatory circuit 21 in the anode circuit of the device.

Variations in the current of the circuit, as caused by the changes produced in the beam of energy when passing through the film, will appear as modulation on the high-frequency current developed in the device. As is well known in the art, efficient transformers for such modulated high frequency currents can be made much cheaper and more compact than would be the transformers required to transmit currents having the frequency of the sound or music recorded on the film 17.

The modulated current is heterodyned with the high-frequency current from the local oscillator and is detected to an intermediate frequency. The remaining transformations, up to the time the signals are reproduced in the loud speaker, are the same as in any superheterodyne receiving system.

If necessary, an additional source of light of adjustable intensity may be provided, whereby to fix the steady-current level of the system.

Another important and useful application of my invention may be made in connection with facsimile transmission, of the type described in the patent to Brandon No. 1,687,489. In systems of the type disclosed therein, a beam of light is caused to traverse a view to be transmitted, the light, as effected by the picture elements, being translated into corresponding electric current through its effect on a two-electrode photo-cell. For amplifying and transmission purposes, a chopper mechanism, comprising a perforated or slitted disc, is rotated in the path of the light to cause the beam of light to be interrupted at a comparatively high frequency, which is reproduced in the current of the photo-cell circuit.

By employing a photo-cell oscillator of the type disclosed in Fig. 1, in lieu of the photo-cell circuit disclosed in the patent, it will be possible to eliminate the chopper mechanism, by generating a high-frequency current in the oscillator and modulating it with the picture-modulated light beam.

In Fig. 4, I have illustrated another application of my invention comprising the combination of a three-electrode photo-cell with an oscillatory circuit of the Hartley type, wherein the three-electrode thermionic device is replaced by the photo-sensitive device 33.

The operation of the oscillator will be under the influence or control of a light source 35 which is adapted to throw a beam of light upon the cathode of the device. By causing the light beam to change intensity in a predetermined or desired manner, the oscillator may be made to function or stop functioning at will, or the oscillatory current may be modulated according to picture elements or the like being scanned for television, or the current may be modulated according to code signals, in which case, the light-interrupting means will constitute a simple non-sparking keying means. Under certain conditions, it may be desirable to provide a steady beam of light for maintaining the oscillator in operation and then employing an independent source of light for modulation purposes.

In Fig. 5, I have illustrated another application of my invention in the form of a signal system embodying a three-electrode light-sensitive device 37. The device, in combination with its locally associated circuits, comprises an oscillator of substantially the same type as that disclosed in Fig. 1, the frequency of which may be determined by the oscillatory circuit 39. The output circuit is inductively or otherwise coupled to the grid circuit 41 of a grid-glow tube 43, the anode circuit 45 of which may be coupled to a source of potential, such as a 60-cycle power source. In the anode circuit to the cathode is provided a relay 47 adapted to be actuated during periods of current flow in the circuit. A current-limiting resistor 49 is also provided for protective purposes. The operation of the relay 47 may be made to depend upon predetermined changes in the potentials induced from the oscillator which would result in the glow tube functioning to bring about the necessary changes in the anode current. A system of the type described would be well suited for traffic control work, the light-sensitive device being mounted on one side of a street near an intersection and a steady beam of light being directed against it from the other side at such elevation that a motor car, approaching the intersection, must intercept the light beam to produce the required changes for operating the signal light, which would be connected in the relay circuit. If it is desired to control traffic at night only, the light-sensitive device may be so located as to be responsive to the light beams from the automobile headlights.

From the above description of my invention, it will be apparent that I have disclosed means whereby the objects of my invention are attained. I have shown how, by employing a grid electrode and utilizing the secondary emission of a photo-cell of the type described, it is possible to increase the sensitiveness of the cell and impart amplifying characteristics to it. I have also shown how such cells may be employed as oscillators in much the same manner as thermionic devices, and also how, by adjusting the anode potential on the device, it will be possible to obtain, at will, either alternating or direct current in the output circuit of the device.

Many changes within the scope of my invention may suggest themselves to those skilled in the art, as well as many applications of photo-cells for use in the manner described by me. I do not desire, therefore, to be limited to the details set forth above, except insofar as is necessitated by the prior art and the appended claims.

I claim as my invention:

1. In combination with an electric discharge device having a photo-sensitive electrode and at least two other electrodes cooperating therewith, means for impressing a positive potential on one of said other electrodes relative to said photo-sensitive electrode, means for impressing a smaller positive potential on the other of said two other electrodes relative to said photo-sensitive electrode, a condenser shunted by an inductance to constitute an oscillatory tuned circuit associated with one of said two other electrodes, a transformer having its primary winding energized by a current flowing through one of said two other electrodes and having its secondary winding connected to a load circuit, a beam of radiant energy incident upon said photo-sensitive electrode and means for varying the intensity of said beam at an audible frequency.

2. In combination, with an electric discharge device having a photo-sensitive electrode and at least two other electrodes cooperating therewith, one of said other electrodes being a grid interposed between said photo-sensitive electrode and the third of said two other electrodes, means for impressing a positive potential on one of said other electrodes relative to said pho-

to-sensitive electrode, means for impressing a smaller positive potential on the other of said two other electrodes relative to said photo-sensitive electrode, a condenser shunted by an inductance to constitute an oscillatory tuned circuit associated with one of said two other electrodes, a transformer having its primary winding energized by a current flowing through one of said two other electrodes and having its secondary winding connected to a load circuit, a beam of radiant energy incident upon said photo-sensitive electrode and means for varying the intensity of said beam at an audible frequency.

3. In combination with an electric discharge device having a photo-sensitive electrode and at least two other electrodes cooperating therewith, means for impressing a positive potential on one of said other electrodes relative to said photo-sensitive electrode, means for impressing a smaller positive potential on the other of said two other electrodes relative to said photo-sensitive electrode, a network tuned to a frequency high compared with ordinary speech and music in circuit with one of said two other electrodes, a transformer having its primary winding energized by current of the frequency of said tuned network and its secondary winding connected to a circuit adapted to operate upon currents of the frequency of said network, a light beam incident upon said photo-sensitive electrode and means to modulate said light beam in accordance with speech or music.

4. In combination with an electric discharge device having a photo-sensitive electrode and at least two other electrodes cooperating therewith, means for impressing a positive potential on one of said other electrodes relative to said photo-sensitive electrode, means for impressing a smaller positive potential on the other of said two other electrodes relative to said photo-sensitive electrode, a network tuned to a frequency high compared with ordinary speech and music in circuit with one of said two other electrodes, a transformer having its primary winding energized by current of the frequency of said tuned network and its secondary winding connected to the circuit arranged to demodulate carrier currents having a frequency of said network, a light beam incident upon said photo-sensitive electrode and means to modulate said light beam in accordance with speech or music.

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