Jan. 13, 1931. A. A. THOMAS 1,788,553

MEANS FOR AND METHOD OF AMPLIFYING ELECTRIC IMPULSES

Filed June 18, 1927

FIG. 1.

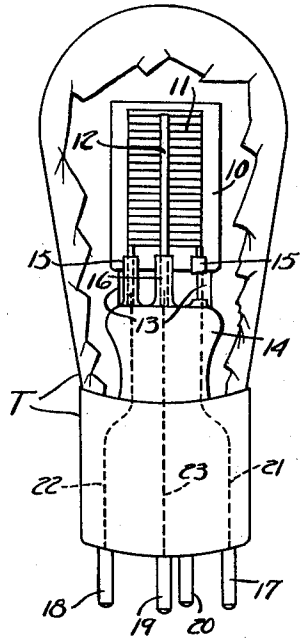


FIG. 2.

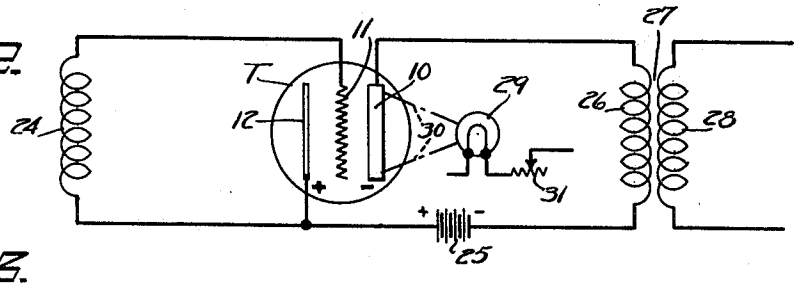


FIG. 3.

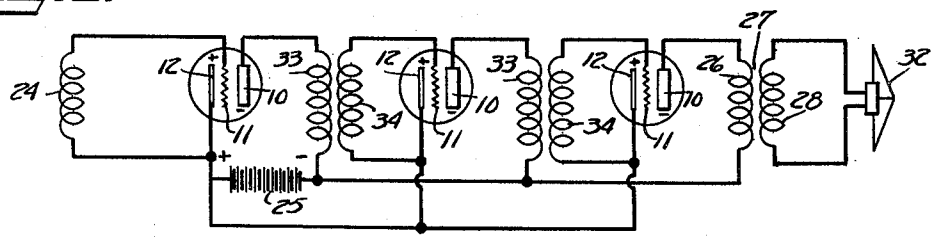


FIG. 4.

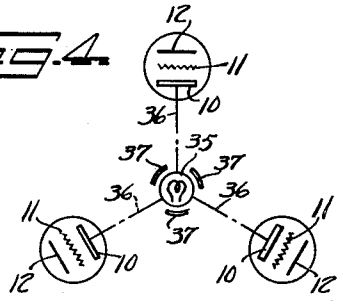
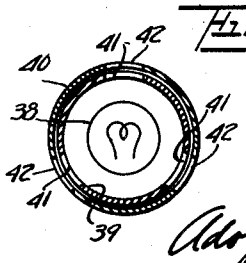


FIG. 5.



INVENTOR

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UNITED STATES PATENT OFFICE

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MEANS FOR AND METHOD OF AMPLIFYING ELECTRIC IMPULSES

Application filed June 18, 1927. Serial No. 199,649.

My invention comprises new systems and apparatus for amplifying feeble electric impulses by utilizing electron discharges in a vacuum tube of novel construction and improved operation. The essential feature of my invention is a vacuum tube free from a filament or other form of electrode to be heated, and this tube is adapted to operate cold for producing electron discharges, thereby obviating many difficulties and objections inherent in the old hot-filament tubes. In other words, I produce and utilize an electronic tube with a cold cathode. It is generally admitted that the greatest trouble with the detector and amplifier tubes of the prior art lies in the filament, which has to be heated to emit electrons. The filament requires a separate source of direct current, popularly known as the "A" battery. Attempts have been made to provide a substitute for the filament battery by so-called eliminators, but these only serve to complicate the apparatus. The use of a hot filament as an electron emitter requires a separate source of heating current and a filament in circuit is always in danger of burning out. In fact, I may say that burnt-out tubes have been the biggest plague in radio since the introduction of De Forest's audion nearly twenty years ago.

According to my present invention, I provide a filamentless vacuum tube in which an electronic stream is produced by a photoelectric element under the influence of light. A second element in the tube is spaced from the photoelectric element, and these two elements are connected in a circuit of substantially constant potential. Between this pair of spaced elements is interposed a third element adapted to be connected in a circuit of variable electric impulses. This third element acts like the grid in the old-type tubes in that it controls the electronic flow between the two spaced elements in accordance with potential variations impressed upon it. The photoelectric element is preferably connected to the negative side of the circuit, so as to have a negative charge and thus facilitate the emission of electrons. The light for influencing the photoelectric element is most conveniently derived from an electric lamp having constant intensity of illumination. In the basic aspect of my invention, the source of light rays to which the photoelectric element is subjected may be outside the vacuum tube or within the tube itself.

My new tube, having no filament or other form of electrode to be heated, requires no "A" battery and cannot burn out. It can, therefore, be employed to great advantage in radio sets, electric phonographs and other amplifying systems, in place of the old filament tubes with only such changes in prior circuits of accepted type as may be found necessary for the best results in any particular case.

I shall explain my invention fully and clearly by reference to the diagrams in the accompanying drawings, in which—

Fig. 1 shows a vacuum tube constructed in accordance with my invention;

Fig. 2 illustrates an amplifying circuit utilizing my new vacuum tube;

Fig. 3 shows a three-stage amplification system embodying my invention for operating loudspeaker mechanism;

Fig. 4 indicates diagrammatically an arrangement whereby three vacuum tubes are operated from a single source of light; and

Fig. 5 shows in plan view an arrangement for controlling the source of illumination by means of an adjustable shutter.

The vacuum tube T, illustrated more or less diagrammatically in Fig. 1, contains a photoelectric element or body 10, a grid 11 and an anode 12. These three electrodes are rigidly supported in properly spaced relation in any practical way. For simplicity I have shown the photoelectric body 10 in the form of a plate supported on stems 13 projecting from the base 14 within the tube. The grid 11 is supported by stems 15, and the electrode 12 is mounted in a stem 16. In order to make Fig. 1 as clear as possible, I have shown the electrodes in diagrammatic form. The element 12 is represented as a rod or stiff wire, but it may be a plate or of any other practical shape or form. A good metal to use for element 12 is aluminum. The grid 11 may be of the usual construction found in radio tubes of the prior art. The photo-

electric body 10 is diagrammatically shown as a flat plate, but it may have any other practical shape, such as a wire, grid, button, and the like. In fact, the electrode 10 may simply consist of a deposit of photoelectric material within the tube in such position that when illuminated it will emit a stream of electrons so directed as to be controlled by the grid. The only reason why the plate 10 appears larger than the grid 11 in Fig. 1 is to show the presence of element 10 behind element 11. The body 10 consists of, or is covered with, wholly or partly, material adapted to emit electrons under the action of light. Among the most active photoelectric materials, especially when exposed to ultra-violet rays, are rubidium, potassium, sodium, barium, and alloys or amalgams containing them.

For the sake of distinction, I shall refer to element 10 as the cathode and to element 12 as the anode, because the photoelectric element 10 operates best as an electron-discharging member when impressed with a negative potential. I do not wish to exclude, however, the possibility of operating the tube by connecting the element 10 as the anode and the element 12 as the cathode. When I speak of container T as a vacuum tube, both in the description and claims, I mean a tube from which the air has been exhausted to the desired degree.

From the base of tube T project four contact pins 17, 18, 19 and 20 arranged to fit in any standard radio tube socket. The pin 17 is connected by wire 21 to the photoelectric body 10. The pin 18 is connected by wire 22 to the controlling grid 11, and pin 19 is connected by wire 23 to electrode 12. The fourth pin 20 is a dummy and is electrically inactive.

In Fig. 2 I have shown a simple circuit containing my new photoelectric tube. One side of an input coil 24 leads to the grid 11, and the other side of the coil is connected to the anode 12, which is connected to the positive pole of battery 25, or any other suitable source of substantially constant potential. The negative side of battery 25 is connected to the photoelectric element 10 through an output coil 26, which in this instance is shown as the primary of a transformer 27. The secondary coil 28 of the transformer is connected to operate any suitable mechanism, such as sound-reproducing apparatus, or any other device adapted to be controlled by variable currents. A source of light 29, which is here shown as an electric lamp giving substantially constant light, is arranged to illuminate the photoelectric element 10, as diagrammatically indicated by dotted lines 30. A rheostat 31 is preferably arranged in the electric light circuit to control the degree or intensity of illumination of lamp 29. In some instances this lamp may be operated by battery 25. If the source of light for cathode 10 is in the tube itself, as previously suggested, a glow discharge may be arranged in close proximity to the cathode.

The operation of the system shown in Fig. 2 is substantially like this: As long as the photoelectric body remains unilluminated, the battery circuit is open between electrodes 10 and 12, and therefore no current flows. When, however, the electrode 10 is subjected to light, particularly ultra-violet rays, a stream of electrons issues from element 10, thereby rendering the space between electrodes 10 and 12 conductive, so that current flows through output coil 26. Assuming the input coil 24 to be traversed by variable electric impulses, which may be produced by radio reception, operation of a phonograph needle, or in any other way, the variable potential impressed on grid 11 will so control the flow of electrons that the current through coil 26 will vary in accordance with, and in greatly amplified relation to, the potential variations of grid 11.

The normal electron discharge of cathode 10 depends on the intensity or quantity of illumination furnished by the lamp 29, and the proper degree or amount of illumination for the best operation of the tube can be determined by trial in each particular case. This lies well within the experimental skill of the worker familiar with this art. By keeping the illumination of electrode 10 constant, a constant stream of electrons is produced.

Fig. 3 illustrates an amplification system employing three of my new photoelectric tubes between the input coil 24 and the output coil 26. The secondary coil 28 operates a loudspeaker 32. The anodes 12 of the tubes are connected in parallel to the positive side of battery 25. One side of the primary coils 33 and 26 is connected to the negative pole of the battery, and the other side of these coils is connected to the cathode 10 of the adjacent tube. The grids 11 of the second and third tubes are connected to the secondary coils 34. Otherwise, what has been said in connection with Fig. 2 applies to Fig. 3 without the need of repetition.

The three tubes of Fig. 3 may be arranged as shown in Fig. 4, so that a single source of light 35 may illuminate the photoelectric elements 10 with the same intensity. The dotted lines 36 represent diagrammatically the paths of illumination for the three lamps. If desired or advisable, mirrors 37 and lenses (not shown) may be employed to direct the light against the elements 10. If more than three tubes are used, these also may be arranged so that a single lamp will be sufficient to operate all of them.

Instead of controlling the degree or intensity of illumination electrically, as indicated in Fig. 2, mechanical controlling means may

be employed. In Fig. 5 there is a lamp 38 surrounded by a fixed shield 39 and a rotary cylindrical shutter 40. Or, the member 39 may be rotary and the member 40 fixed. The shield 39 has windows 41, and the shutter 40 has correspondingly arranged windows 42. By adjusting the shutter 40 (or 39), the amount of light reaching the photoelectric element of the lamp or lamps may be regulated as required. In Fig. 5 it has been assumed that the lamp controls three tubes, as in Fig. 4. The number of windows in the cylindrical members 39 and 40 will depend upon the number and arrangement of the lamps to be operated. It is hardly necessary to explain that the light from lamp 29 or 35 strikes the front face of each cathode 10. The relative arrangement of the lamp and vacuum tubes in Figs. 2 and 4 is merely diagrammatic. So far as my new amplifying system is concerned, any practical form of photoelectric tube may be used.

It will be clear from the preceding description that I have provided a vaccum tube having marked advantages over the old type three-electrode tubes. As far as I know, this is the first radio tube adapted to operate cold. There being no filament or other electrode to be heated, it is impossible for the tube to burn out. Even if the electrodes should be accidentally connected to the wrong battery terminals, no harm would be done. Electrically speaking, therefore, the life of of the tube is practically indefinite, it being subject only to mechanical breakage. Furthermore, the hum or line noises due to filament circuits are completely eliminated by the use of my cold cathode tube, so that better radio reception is obtained. The electron discharge of the cold photoelectric element 10 does not depend upon the heating action of an electric current, as in the case of hot-filament tubes, but depends upon a source of light which may be regulated to produce the required electron flow for the most sufficient operation of the tube and the system in which it is connected.

I claim as my invention:

1. In a system for amplifying electric impulses, a plurality of operatively connected vacuum tubes having each a pair of spaced electrodes and an interposed grid, one electrode of each pair being adapted to emit electrons under the action of light, and a single source of light so arranged in relation to said vacuum tubes as to illuminate the photoelectric elements of all tubes with substantially the same degree of intensity.

2. An electric amplifying system comprising a plurality of vacuum tubes, each tube having a pair of spaced electrodes and an interposed grid, one electrode of each pair being adapted to emit electrons under the action of light, means for connecting each pair of electrodes in a circuit of substantially constant potential, means for connecting the grid of the first tube in an input circuit of variable potential, said tubes being connected to provide successive stages of amplification, and a single source of light so arranged in relation to said vacuum tubes as to illuminate the photoelectric elements of all tubes with substantially constant intensity.

3. An electric amplifying system comprising a vacuum tube containing a pair of spaced electrodes, one of said electrodes being an anode and the other being a cathode adapted to emit electrons under the action of light, means for connecting said electrodes in a circuit of substantially constant potential, a grid interposed between said electrodes, an input coil connected to said anode and said grid, and an output coil connected to said anode and cathode, whereby changes in grid potential correspondingly vary the current flow in said output coil in amplified ratio.

4. An electric amplifying system comprising a vacuum tube containing a pair of spaced electrodes, one of said electrodes being an anode and the other being a cathode adapted to emit electrons under the action of light, means for connecting said electrodes in a circuit of substantially constant potential, a grid interposed between said electrodes, an input coil connected to said anode and said grid, and an output coil connected to said anode and cathode, whereby changes in grid potential correspondingly vary the current flow in said circuit in amplified ratio, and means for varying the intensity or quantity of illumination of said light-sensitive electrode in order to control the normal electronic discharge thereof.

5. In a photo-electric system, the combination of a plurality of vacuum tubes arranged in a circle, each tube containing a photo-electric element, and an electric lamp placed substantially at the center of said circle for illuminating said elements with practically the same degree of intensity.

6. In a photo-electric system, the combination of a plurality of vacuum tubes arranged in a circle, each tube containing a photo-electric element, an electric lamp placed substantially at the center of said circle for illuminating said elements with practically the same degree of intensity, and a rotary cylindrical shutter surrounding said lamp to regulate the amount of light projected onto said elements.

7. An electric amplifying system comprising a plurality of vacuum tubes, each tube having an anode and a photo-electric cathode, a grid interposed between said two electrodes in each tube, means for connecting the anode and cathode of each tube in a circuit of substantially constant potential, each of said circuits including a primary coil, a secondary coil associated with the primary coil between each pair of tubes, each secondary coil being

connected to the anode and grid of the associated tube, an input coil connected to the anode and grid of the first tube, an output circuit associated with the last tube, and means for simultaneously illuminating all of said photo-electric cathodes with substantially constant intensity.

8. In a photo-electric system, the combination of a single source of light, and a plurality of photo-electric tubes grouped about said source of light in such a way that the light-sensitive elements of said tubes are simultaneously illuminated with practically the same intensity.

9. A radio receiver system having a plurality of vacuum tubes connected to provide successive stages of amplification, each tube having a pair of spaced electrodes and an interposed grid, one electrode of each pair being adapted to emit electrons under the action of light, and means for simultaneously illuminating said electrodes with substantialy constant intensity to provide anode circuits which normally are of substantially constant potential.

10. An electric amplifying system comprising a plurality of vacuum tubes, each tube having an anode and a photo-electric cathode, a grid interposed between said two electrodes in each tube, means for connecting said tubes to provide successive stages of amplification, an input circuit connected to the first tube and an output circuit connected to the last tube, and means for simultneously illuminating all of said photo-electric cathodes with substantially constant intensity.

ADOLPH A. THOMAS.