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2,568,449

ELECTRONIC COUNTER

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Fig. 1.

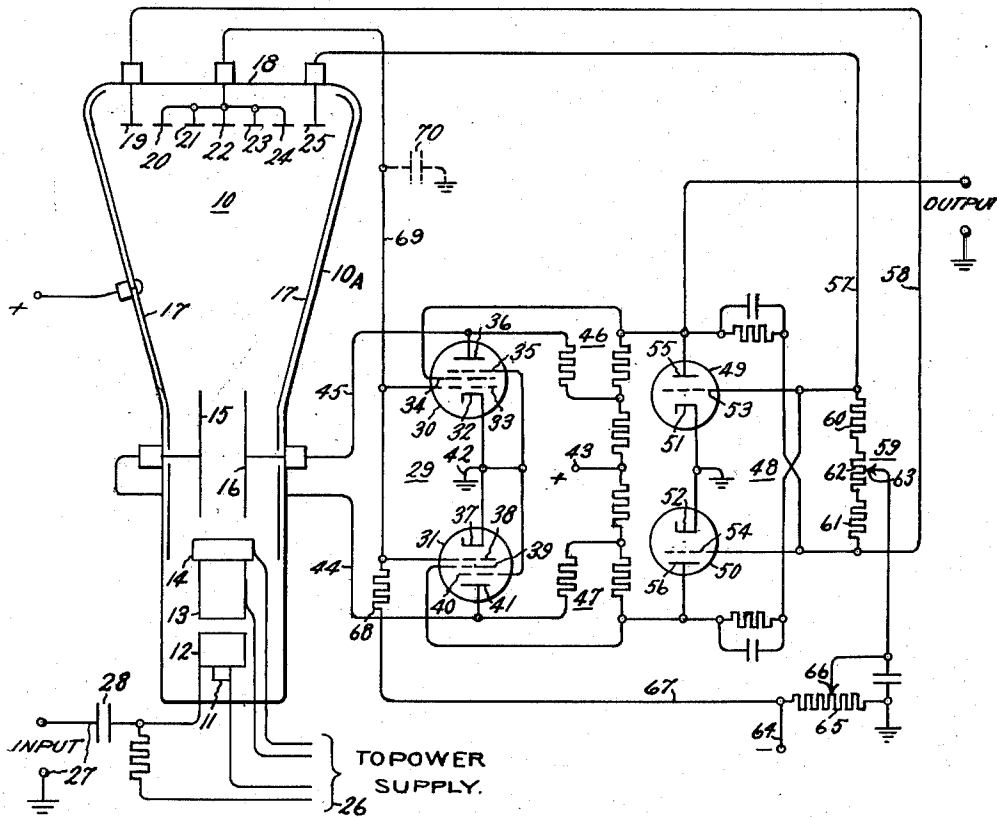


Fig. 2.

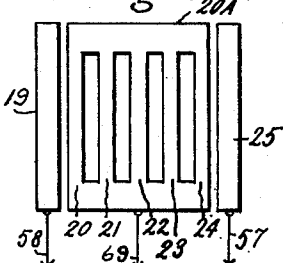


Fig. 3.

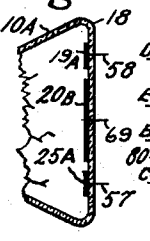


Fig. 4.

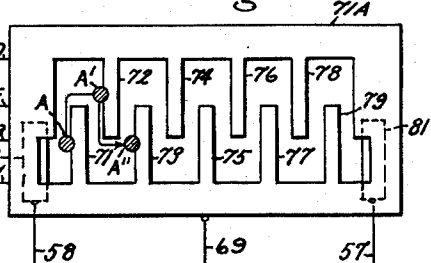
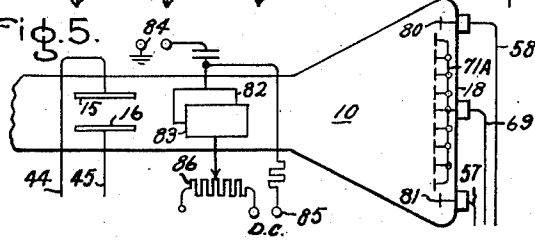


Fig. 5.



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UNITED STATES PATENT OFFICE

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ELECTRONIC COUNTER

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4 Claims. (Cl. 315—21)

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This invention relates to electronic counters utilizing electron beam devices of the multiple-anode type.

An object of this invention is to provide a new and improved electronic counter.

Another object is to provide an improved electronic counter which is capable of counting electric pulses at rates up to 10^6 pulses per second.

A further object is to provide an improved electronic counter which has a greatly reduced number of components compared to conventional counting circuits.

Another object is to provide an improved electronic counter which is especially adapted for use as a timing generator for television systems, and for other purposes.

In this invention, there is provided an electron beam device of the cathode-ray type which has a multiple-anode structure hereinafter described, and an electric circuit connected to beam-deflecting plates in the electron beam device which controls the lateral movement of the electron beam from one anode to another responsive to the pulses counted, so that a counting ratio is obtained which depends solely upon the construction of the multiple anode structure. In the preferred embodiment, the anode structure comprises a plurality of parallel anodes arranged in a row substantially parallel to the direction of the electron beam. The anodes on each end of the row function as reversing electrodes, while those in between serve as counting electrodes. All of the anodes are of material having a secondary emission ratio substantially greater than one. The controlling circuit comprises a flip-flop or switching circuit so connected to the reversing electrodes that when either electrode is struck by the electron beam, the secondary emission current produced triggers the switching circuit which, in turn, effects a reversal in polarity of the voltage between beam deflecting plates of the electron-beam device. Since the polarity of voltage between the deflecting plates determines the direction of lateral movement of the electron beam, the electron beam reverses its direction of lateral movement each time a predetermined number of pulses is counted and the electron beam arrives at one of the end anodes. For example, five counting electrodes may be provided, which makes a total of seven anodes including the two reversing electrodes. As pulses are counted, the electron beam moves from the first to the fifth counting electrode, and then to one of the reversing electrodes. Thereupon the voltage between deflecting plates is reversed in polarity, and the beam retraces its path in the opposite direction until it reaches the other reversing electrode. In completing a full cycle of operations, the beam passes over each counting electrode twice. Therefore, the counting ratio

is two times the number of electrodes, or 10:1 in the example given. This counting ratio may be increased by simply adding more counting electrodes. Thus, a high counting ratio with relatively few components is possible. The reversing electrodes not only double the counting ratio of the device, but also increase the maximum counting speed, since they make possible the elimination of the relatively long time interval which otherwise would be required to return the beam to starting position after it passed the last counting electrode.

The features of the invention which are believed to be novel and patentable are set forth in the appended claims. For a better understanding of the invention reference is made in the following description to the accompanying drawing, in which Fig. 1 is a diagrammatic representation of one embodiment of the invention; Fig. 2 is an illustration of a preferred anode structure utilized in the electron beam device shown in Fig. 1, Fig. 3 illustrates a modification of the anode structure of Fig. 2; Fig. 4 is an alternative anode structure; and Fig. 5 is a schematic diagram illustrating the changes necessary to utilize the anode structure of Fig. 4.

Referring now to Fig. 1, an electron-beam device 10 comprises an envelope 10A, which contains an electron emissive cathode 11, a control grid 12, a pair of accelerating and focussing electrodes 13 and 14, a pair of deflecting plates 15 and 16, and an electrically conductive coating 17. These component parts are similar to those found in a conventional cathode ray oscillograph tube. The fluorescent screen which is at the large end of the envelope in an oscillograph tube may be omitted for some applications of the present device, and may be included for others, as explained hereinafter. Adjacent to the large end 18 of envelope 10A is an anode structure which comprises a plurality of parallel anodes or targets 19, 20, 21, 22, 23, 24 and 25. More specifically, the targets 19 and 25 will be referred to as reversing electrodes and the targets 20—24 as counting electrodes. Preferably, the exposed surfaces of the anodes are constructed of an electrically conductive material having a secondary emission ratio substantially greater than one. For example, anodes coated with magnesium oxide or beryllium oxide may be used. The preferred configuration is illustrated in detail in Fig. 2. The number of counting electrodes 20—24 determines the counting ratio of the tube. The end or reversing electrodes 19 and 25 take part in changing the direction of the lateral movement of the electron beam as it leaves either electrode 20 or 24, as hereinafter explained.

A conventional power supply, not shown, connected to terminals 26 furnishes the required voltages for operation of the electron beam de-

vice. The voltage values for best operation of a particular device may be determined by methods known to those skilled in the art pertaining to cathode ray oscillograph tubes and similar electron-beam devices.

In the embodiment illustrated in Fig. 1, a source of negative pulses to be counted is connected to input terminals 27. The negative pulses are transmitted through coupling capacitor 28 to control grid 12. Pulses to be counted should have an amplitude large enough to drive control grid 12 sufficiently negative to momentarily interrupt the electron beam.

Potentials for controlling the lateral movement of the electron beam are supplied to the deflecting plates 15 and 16 by a voltage-control circuit 29 which comprises two amplifiers which respectively include vacuum tubes 30 and 31. Tube 30 comprises a cathode 32, a control grid 33, a screen grid 34, a suppressor grid 35 which is connected to cathode 32, and an anode 36. Tube 31 is similar to tube 30, and comprises a cathode 37, a control grid 38, a screen grid 39, a suppressor grid 40 connected to cathode 37, and an anode 41. Both cathodes are connected to a common ground terminal 42. Anode voltage for tubes 30 and 31 is supplied through resistance networks 46 and 47 from a conventional direct current supply circuit, not shown, which has its positive terminal connected to terminal 43 and its negative terminal connected to ground. The potentials of anodes 41 and 36 are applied to deflecting plates 15 and 16, respectively, through connections 44 and 45.

Tubes 30 and 31 are caused to operate alternately under the control of a flip-flop circuit 48. This flip-flop circuit comprises a pair of electron discharge tubes 49 and 50 having, respectively, cathodes 51 and 52, control grids 53 and 54, and anodes 55 and 56. Anode voltages for tubes 49 and 50 are supplied from terminal 43 through the respective resistance networks 46 and 47. These tubes function as switching devices under the control of the reversing electrodes 19 and 25, as explained hereinafter. The reversing electrodes 19 and 25 are connected, respectively, by a pair of conductors 57 and 58 to the control grids 53 and 54. A resistance network 59 comprises two resistors 60 and 61 of fixed value and a resistor 62 which is connected between the first-mentioned resistors. All three resistors 60-62 are connected in series between the control grids 53 and 54. Resistor 62 is provided with an adjustable tap 63 connected through a resistor 65 and adjustable tap 66 to terminal 64, to which a source of negative bias voltage, not shown, is connected. Tap 66 provides means to adjust, simultaneously, the bias voltage applied to the grids 53 and 54, and tap 63 is used to adjust the relative bias voltages applied to the two grids. Terminal 64 is also utilized to supply a bias voltage to grids 33 and 38, and is connected to these grids through a conductor 67 and resistor 68. Grids 33 and 38 are tied together and connected by a conductor 69 to the counting electrodes 20-24.

Fig. 2 illustrates the preferred structure of anodes 19-25. The exposed surfaces of these electrodes are made of a material, beryllium oxide for example, capable of producing secondary emission currents when struck by the electron beam. The reversing electrodes 19 and 25 are suitably supported within envelope 10A, and are insulated from each other and from the counting electrodes. The counting electrodes 20-24 may be stamped out of a single piece of material in the

form of a grid 20A having any desired number of parallel strips (20-24), depending on the counting ratio desired as will be presently explained. The illustrated construction of the counting electrodes permits the use of very simple and straightforward supporting means, which provides a decided economy in the manufacture of such devices. Obviously, the electron receiving electrodes could be simplified further by utilizing a metallic conducting paint, applied, for example, on an insulating material such as glass. The conducting material must, of course, have a secondary emission ratio substantially greater than one. Electrons which strike the insulating material build up a small surface charge thereon. This raises the potential of the insulating surface a few volts, but not enough to substantially alter the path of the electron beam. The small rise in potential, however, is sufficient to increase the secondary emission ratio of the insulating material to one, so that thereafter an equilibrium exists between the number of electrons arriving at the insulating surface and those leaving due to secondary emission. The electrons which are emitted travel to coating 17.

In Fig. 3 is illustrated a plurality of electron-receiving electrodes 19A, 20B and 25A arranged to be disposed on the inner surface of the portion 18 of the envelope 10A by vacuum evaporation of a metal, such as aluminum or silver. The proper electrode pattern can be arranged by making this disposition of the material through a mask designed in accordance, for example, with the electrodes illustrated in Figs. 2 and 4. Subsequently, its secondary emission ratio could be substantially increased by the evaporation through the same mask, of an extremely thin film of magnesium (Mg) or beryllium (Be), and this film, in turn, oxidized by baking in air to produce a surface having a thin film of MgO or BeO. Such a surface gives a high secondary emission yield. The ratio of this emission to the primary emission being substantially greater than one.

Referring to Fig. 1, assume that tube 30 is conducting and that the potential of grid 33 is such that the electron beam is directed into the space between electrodes 19 and 20. As a result, no current flows to electrode 20 and the grid 33 of the tube 30 is rapidly driven more negative as the wiring and electrode capacitances discharge through resistor 68. As grid 33 becomes more negative, anode 36 becomes more positive; and since deflecting plate 16 is connected to the anode 36, a right-hand deflection (with respect to the observer) of the electron beam occurs. This deflection continues until the beam strikes the counting electrode 20. If the entire cross-section of the beam should strike electrode 20, a secondary emission current would be set up which is more than sufficient to counteract the discharge of circuit capacitances through resistor 68, and thus tends to drive grid 33 more positive and deflects the electron beam to the left. As a result, an automatic servo action exists which causes the beam to come to rest partly on and partly off electrode 20, in such a way that the secondary emission current is substantially equal to the current through resistor 68. The electron beam then remains on the left edge of counting electrode 20 until an impulse of negative polarity arrives at the input circuit 27. This negative impulse momentarily interrupts the electron beam by driving control grid 12 to cut-off, and so interrupts the secondary-emission current. During this interruption, discharge of the circuit

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capacitances through resistor 68 is resumed, so that at the end of the input pulse the electron beam is reestablished on a path which is to the right of electrode 20, and which may pass between electrodes 20 and 21 if the input pulse is of the proper duration. The beam thus travels to the left edge of electrode 21, whereupon secondary emission current arrests the lateral movement. A tolerance of the order of plus or minus 50% in the duration of the input impulse is allowable, since if the electron beam falls anywhere in the spaces between the electrodes or on them, it will automatically seek to the left edge of the electrode. This relatively large tolerance of adjustment is one of the principal advantages of this counting system over the previously used chains of multi-vibrators used in radar or television timing generators.

The electron beam progresses from one counting electrode to the next in response to each negative impulse arriving at the input circuit 27. This progression continues until the last electrode 24 is passed, whereupon the electron beam strikes the right-hand reversing electrode 25. The flow of secondary emission current from this last-mentioned electrode applies a positive impulse to grid 53 of tube 49 and transfers current from tube 50 to tube 49 by the switching action of flip-flop circuit 48. This reduces the potentials applied to screen grid 34 and anode 36 and raises the potentials applied to screen grid 39 and anode 41. When this occurs, tube 30 becomes nonconducting and tube 31 assumes control of the electron beam deflection. When this switching action occurs there is a tendency to deflect the electron beam rapidly to the left. However, capacitances of the wiring and the deflecting plates prevent the beam being deflected instantaneously to the left side of the anode structure; therefore, the beam in moving to the left strikes anode 24, and produces a secondary emission current sufficient to arrest further deflection to the left. The beam may be deflected back into the space between anodes 24 and 25 for an instant due to sudden over-correction. From symmetry conditions it is evident that the counting tube 10 will now perform just as before except that the electron beam will progress from right to left. The arrival of negative impulses at input 27 will cause the beam to jump from one counting electrode to the next until it reaches the left reversing electrode 19, whereupon the flip-flop circuit again operates to restore the initial conditions.

It is evident that in completing a full cycle of operations the beam will pass over each counting electrode (20—24) twice and, therefore, the counting ratio is twice the number of counting electrodes or ten to one for the structure shown in Fig. 2. This ratio may be increased to 1000 to 1, for example, by simply adding more counting electrodes. This high counting ratio with relatively few components is another advantage of the invention.

The counting speed is limited only by the rate of discharge of circuit capacitances through resistor 68 and by the reversal time of flip-flop circuit 48. With this present invention it is possible to count impulses of the order of 1,000,000 per second. If a slower counting speed is desired for longer impulses, it is only necessary to add a capacitor 70 of appropriate value between ground and conductor 69 to reduce the rate of discharge of circuit capacitances through resistor 68.

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The particular embodiment above described is adapted to maintain a fixed ratio between two frequencies, for example, in a television control system. If visual indication of the impulses is desired, it is only necessary to include within the envelope 10A a fluorescent screen at the large end 18 of the envelope to indicate the position of the electron beam. If it is desirable to reset the system to zero before a count is made, this can be done by momentarily biasing the deflection plates through a suitable circuit to that voltage which will cause the beam to fall on the left-hand reversing electrode 19. When this bias is released, the system will be in the initial condition.

The counter illustrated in Figs. 1 and 2 provides means for counting pulses of substantially uniform duration and either uniform or random repetition rate. In order to count impulses having random duration, it is preferable to use a counter having an anode structure as illustrated in Fig. 4. Referring now to Fig. 4, a counting electrode structure 71A comprises a plurality of anodes 71 to 79, inclusive, arranged in two interleaved rows in the form of a grid in which the unattached ends of the electrodes 72, 74, 76, and 78 extend into the spaces formed by the unattached ends of the electrodes 71, 73, 75, 77 and 79. A pair of reversing electrodes 80 and 81 are provided at the opposite ends of the anode structure, and operate in the same manner as the reversing electrodes 19 and 25 of Fig. 1. The anodes may be constructed as described in connection with electrodes 19—25 or they may be constructed as illustrated in Fig. 3.

When the counting electrode structure 71A is utilized, the electron beam device 10 must incorporate, as illustrated in Fig. 5, a second pair of deflecting plates 82 and 83. These plates provide the means, when suitably energized, to deflect the electron beam perpendicular to the direction of deflection provided by plates 15 and 16. In relation to Fig. 5, plates 15 and 16 deflect the electron beam vertically, and plates 82 and 83 deflect the electron beam perpendicular to the plane of the drawing. Terminals 84 are provided for connecting the source of pulses counted to deflecting plates 82 and 83, rather than to the control grid as in Fig. 1. Terminals 85 and an adjustable tap-resistor 86 are provided for connecting to plates 82 and 83 a suitable D.-C. source, not shown, to provide proper operating potential to these deflecting plates. Otherwise, the apparatus is similar to that illustrated in Fig. 1.

The operation of the apparatus shown in Figs. 4 and 5 is essentially the same as described in connection with the embodiment of the invention illustrated in Figs. 1 and 2. For example, referring to Fig. 4, assume that an electron beam A is resting on the left edge of electrode 71 and that the bias on the vertical plates 82—83 is arranged so that this rest position is slightly lower than the ends of any of the upper electrodes (72, 74, 76 or 78). If now an impulse is applied to input circuit 84, the beam will rise clear of electrode 71 and come to rest against the left edge of electrode 72, as designated by A' in Fig. 4. Termination of the impulse at any later time will allow the electron beam to drop below the lower end of electrode 72 and come to rest on the left edge of electrode 73, as designated by A'' in Fig. 4, where it will remain until the arrival of the next impulse at input 84.

The positioning of the electron beam substantially between points B and C, Fig. 4, may be ac-

complied by adjusting the direct current potential applied to deflecting plates 82 and 83 by adjusting the tap position on resistor 86; while positioning of the electron beam between points D and E is accomplished by limiting the amplitude of the impulse signal applied to the input circuit 84. Means for amplitude limiting is well-known in the art and is therefore omitted from the present description.

The utilization of the electrode structure of Fig. 4 in combination with the circuit above described enables one to count impulses of random duration and random interval such as occur in nuclear disintegration.

Other arrangements for utilizing the present invention may suggest themselves. For example, instead of impressing the impulse directly on the vertical deflecting plates as described, a second flip-flop circuit could be utilized. The input pulse would be applied to the triggering terminals of this circuit, and the output terminals of the flip-flop circuit would be connected to plates 82-83, to switch the polarity of voltage between these plates responsive to each input pulse. Such an arrangement would alternately cause the electron beam to move from midway between B and C to midway between D and E and so on, in accordance with the impulses applied to the flip-flop circuit.

The embodiments of the present invention which have been illustrated and described have been selected for the purpose of setting forth the principles involved. It will be obvious that the invention may be modified to meet various conditions for different specific uses and it is, therefore, intended to cover by the appended claims all such modifications which fall within the spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Apparatus for counting electric pulses, comprising means to form an electron beam, an anode structure including a plurality of counting electrodes, beam deflecting means, voltage control means connected to the deflecting means to apply thereto a deflecting voltage of variable magnitude to cause the electron beam to move laterally from one counting electrode to another responsive to the electric pulses counted, the voltage control means being connected to the counting electrodes and responsive to electric current flowing thereto to arrest lateral movement of the electron beam between the pulses counted, reversing electrodes at respective ends of the anode structure, a flip-flop circuit having respective input triggering terminals connected to said reversing electrodes and having output terminals connected to the voltage control means, so that whenever the electron beam strikes one of the reversing electrodes the flip-flop circuit is triggered and thereby reverses the polarity of voltage applied to the beam deflecting means, whereby the direction of lateral movement of the electron beam is reversed.

2. Apparatus for counting electric pulses, comprising means to form an electron beam, an anode structure including a plurality of counting electrodes, beam deflecting means, voltage control means to control the magnitude of voltage applied to the deflecting means, said voltage control means being connected to the counting electrodes and responsive to electric current flowing thereto to cause lateral movement of the electron beam

from one counting electrode to another when such current is absent and to arrest such movement when such current is present, input terminals for the pulses to be counted, a control grid positioned in the path of the electron beam and connected to said input terminals, so that negative pulses applied to the input terminals interrupt the electron beam and thus permit changes in the voltage applied to the deflecting means, whereby the beam is moved laterally from one counting electrode to another responsive to such negative pulses.

3. Apparatus for counting electric pulses, comprising means to form an electron beam, an anode structure including a plurality of counting electrodes arranged in two interleaved rows, first deflecting means to move the electron beam laterally from one counting electrode to another in the same row, voltage-control means connected to the counting electrodes and responsive to current flow thereto to arrest such movement, second deflecting means to move the electron beam from one row to the other, input terminals for the pulses to be counted, and a flip-flop circuit having triggering terminals connected to said input terminals and output terminals connected to said second deflecting means, so that electric pulses applied to the input terminals trigger the flip-flop circuit, thus reversing the polarity of voltage applied to the second deflecting means and moving the electron beam from one row of counting electrodes to the other, whereby the electron beam travels a zig-zag path from one end of the anode structure toward the other end responsive to successive pulses counted.

4. Apparatus for counting electric pulses, comprising means to form an electron beam, an anode structure including a plurality of counting electrodes arranged in a row substantially perpendicular to the direction of such electron beam and reversing electrodes at respective ends of the row, beam-deflecting plates arranged on opposite sides of the electron beam to deflect the beam from one counting electrode to another, two amplifiers having their output terminals connected to respective ones of the deflecting plates and their input terminals connected together and to the counting electrodes, a flip-flop circuit connected to bias to cut-off one or the other of the two amplifiers selectively, said flip-flop circuit having respective triggering terminals connected to the reversing electrodes, a control grid positioned in the path of the electron beam, and input terminals for the pulses to be counted connected to said control grid.

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