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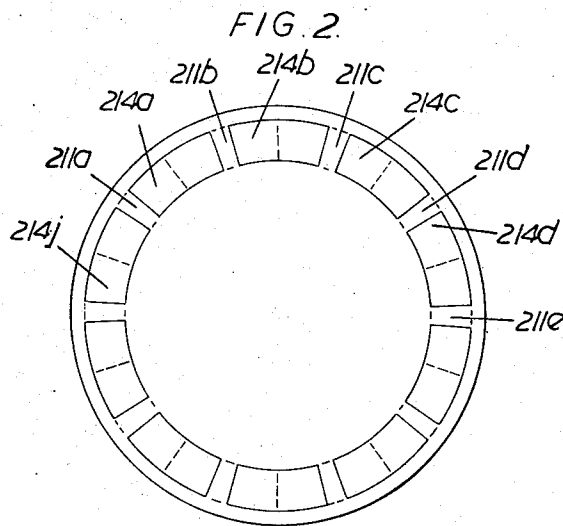
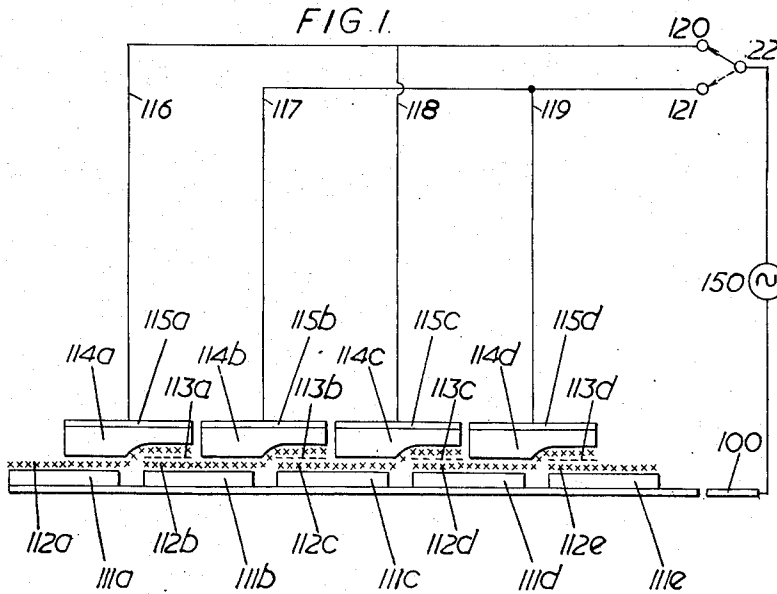
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STEPPING OR COUNTING DEVICE

Filed June 29, 1959

2 Sheets-Sheet 1



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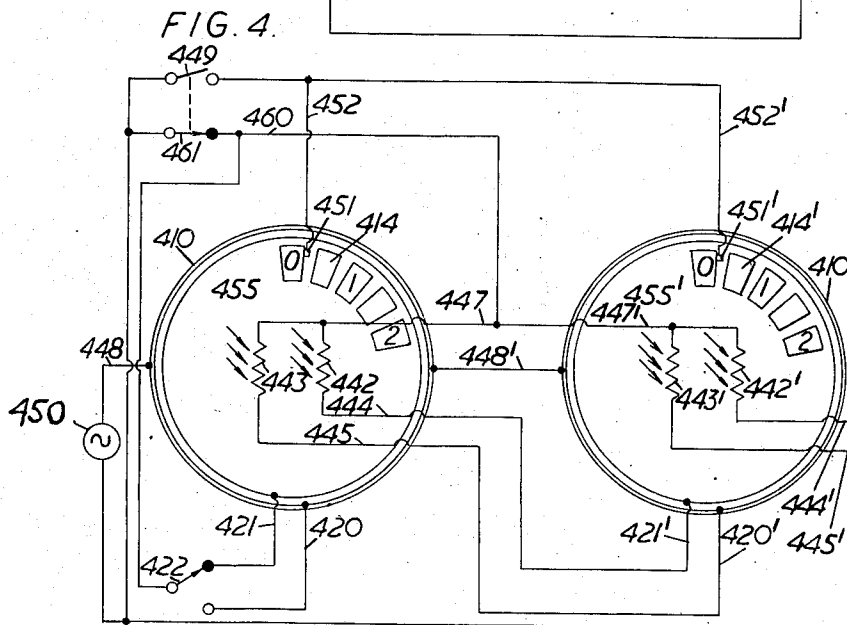
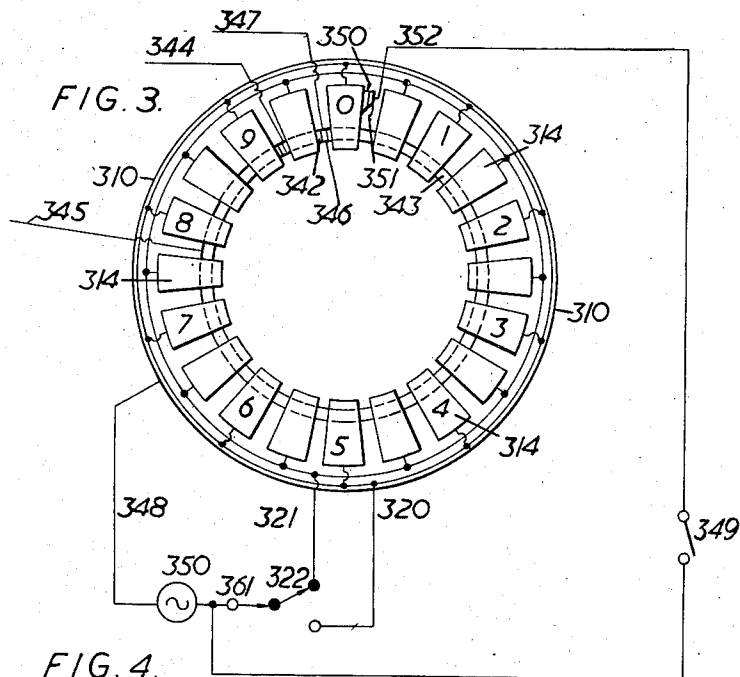
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STEPPING OR COUNTING DEVICE

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This invention relates to improved stepping or counting devices and particularly to such devices in which the switching action is effected by the action of light on photoconductive material. The light is preferably produced by the excitation of electroluminescent material.

A photoconductor is a material which has a high resistance when no light is incident upon it, but which has a low resistance when illuminated. By way of example, a typical cadmium sulphide photoconductor in a 0.02 by 0.2 inch gap is capable of conducting a photocurrent of the order of 100 microamperes when exposed to 0.05 foot candle illumination and to provide a ratio of photocurrent to dark current greater than 10^4 . For convenience in this specification a photoconductor will hereinafter be said to be "conducting" when illuminated and "non-conducting" when not illuminated although obviously these expressions are only relatively correct.

By electroluminescent material is meant material which luminesces when excited by an alternating electric field. Many such materials are known and are obtainable commercially. A typical material is an activated zinc sulphoselenide, which may be excited by an alternating current field to produce light having a broad emission spectrum.

Stepping or counting devices according to the invention which operate by a combination of the electroluminescent and photoconductive effects have the advantage of great simplicity, ease of manufacture, low power consumption and small size. In addition such devices have the advantage that they are readily driven from each other.

The invention will now be described by way of example and with reference to the drawings, in which:

FIGURE 1 shows schematically a section through an elementary device according to the invention;

FIGURE 2 shows a plan view of another form of the device of FIGURE 1;

FIGURE 3 shows a plan view of a device according to the invention having driving and output arrangements, and

FIGURE 4 shows schematically two of the devices of FIGURE 3 connected in cascade.

In the drawing, three different devices are depicted, each consisting of the same basic elements and to avoid confusion reference numerals for the same elements will be given the same number prefixed by the number of the relevant figure. Thus element 111 of FIGURE 1 will appear as 211 in FIGURE 2 and so on.

Referring first to FIGURE 1 a counting device comprises a conducting base plate 100 carrying layers of photoconductive material 111a-111e. Superimposed upon the layers 111a . . . e are transparent layers of conductive material 112a . . . e which layers cover not only one layer for example 111a but also part of the next layer for example 111b. Where the layers of conductive material overlap as for example at the left hand end of 111b, 111c, etc. they are insulated from each other by layers 113a-d of transparent insulating material. Overlying one half of each of two adjacent photoconductive layers 111, and on top of conducting layers 112 and layers 114a . . . d of electroluminescent material. Each electroluminescent element has superimposed upon it a conducting layer 115a . . . d. Alternate conducting layers 115 are connected by way of 116 and

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118 to one pole 120 of a switch 122. The other layers 115 are connected by 117 and 119 with the other pole 121 of the switch. The moving contact of the switch 122 and the base 100 are connected to a source of alternating current 150 as shown.

In the embodiment being described the photoconductive layers were produced by mixing powdered activated cadmium sulphide with a 1% solution of ethyl cellulose in isoamyl alcohol and spraying the resulting mixture on to the baseplate 100 through a suitable apertured mask. The layers were sprayed to a thickness of approximately $\frac{1}{1000}$ inch. A suitable activated cadmium sulphide is that sold by Radio Corporation of America under type number F-2103.

The layers of transparent conducting material are preferably of cadmium oxide deposited upon the layers 111 by a vacuum deposition process, upon which the insulating layers 113 are applied. These layers are sprayed on, using a suitable transparent resin or varnish, after which a further conducting layer of cadmium oxide is deposited to provide a conductive layer above the insulating layer and in contact with the conductive layer to its left as shown in FIGURE 1.

A suitable varnish is a synthetic resin varnish such as a stoving enamel, which is subsequently cured by baking.

The conducting layer of cadmium oxide is preferably produced by reactively sputtering cadmium metal in an atmosphere of 5% oxygen in argon, the layers being confined by means of masks in known manner. (Transparent conductive and insulating layers are not shown in FIGURE 2.)

The electroluminescent elements may be prepared in a similar manner to the photoconductive layers previously mentioned, using an activated zinc sulphoselenide electroluminescent material such as that sold by Radio Corporation of America under type number F-2110. The layers are $\frac{1}{4000}$ inch thick.

The foregoing described a simple device in accordance with the invention and before proceeding to the description of more complex embodiments it will be helpful to understand its operation, which will be described with reference to FIGURE 1.

With the switch in the full-line position shown suppose the left hand part of layer 111a to be momentarily illuminated by an external source of light. The left hand part of layer 111a will then commence to conduct. Layer 112a is a conductor and because 111a is conducting 112a will assume a potential near to that of the base 100. The left hand end of the luminescent element 114a is now excited because of its position between the electrodes formed by conducting layers 112a and 115a which are connected to the alternating current supply shown. Because layer 112a extends to cover the whole of the lower surface of the luminescent element 114a the whole element is excited and glows. The right hand part of the glowing luminescent element 114a is superimposed upon the left hand part of photoconductive element 111b and is separated therefrom by transparent layers 112a, 113a and 112b, so that when element 114a is glowing the left hand end of element 111b becomes a conductor. It cannot however conduct because it is insulated from electrode 115a by an insulating layer 113a, and from electrode 115c by insulating layer 113b. The situation then is that element 111a is conducting element 114a is glowing and the left hand part of element 111b is conductive but not conducting.

If now the switch is moved to its dotted line position (i.e. to remove the alternating current supply from 120 and apply it to 121) electroluminescent element 114a loses its excitation and stops glowing while the left hand part of photoconductive layer 111b commences to revert to a non-conductive state. If the operation of the switch

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is sufficiently fast compared with the decay time of the photoconductive material current will flow through the left hand part of 111b to excite luminescent element 114b by way of conducting layer 112b and luminescent element 114b will glow and maintain the right hand part of element 111b in a conductive state, at the same time priming photoconductive element 111c by illuminating the left hand end of 111c. Element 114c will not be excited because there is no potential on electrode 115c but will be excited if switch 122 is moved back to energise line 120, current flowing by way of base 100, element 111c and layer 112c. Excitation of line 120 applies alternating current by way of line 118 to electrode 115c and also by way of line 116 to electrode 115a, but layer 114a is not excited because insulating layer 113a is interposed between conductive layers 112a and 112b. It will now be apparent that movement of switch 122 alternately between lines 120 and 121 will switch the device so that layers 114a, 114b, 114c and 114d are caused to emit light, in that order. The action cannot occur in reverse order because the insulating layers 113 prevent current flow between a photoconductive element and the electrode 115 of the electroluminescent element on its left. If the device just described were constructed in circular form, as shown diagrammatically in plan view in FIGURE 2 so that the last luminescent layer, for example 214f overlapped the left hand part of photoconductive layer 211a continuous operation of switch 122 would step the glow around the circle continuously.

It will be apparent that the time of changeover of switch 122 must be fast compared with the decay time of the photoconductive material. This switch is not necessarily a mechanical switch as shown in FIGURE 1, but may for example comprise two layers of photoconductive material where each layer is alternatively illuminated by a source or sources of light, which may be electroluminescent. In this way a purely electrical drive may be provided. It will be further apparent that many known circuits, for example flip-flops and other bistable devices, may be employed for this purpose.

In many cases it is necessary to produce an output signal from a counting device which may, for instance, provide a "carry" signal to drive a counting device in the next order. In the device under consideration an output signal may be obtained when any layer 114 is luminescing if the elements 114, layers 112 and electrodes 115 relating to that element 114 are suitably extended and provided with separate photoconductive layers (called "output layers"). In this way a change in resistance of an output layer will occur whenever its associated electroluminescent element 114 is excited. It will be obvious that such a change in resistance may be employed to provide a drive for the next counter in a chain without the necessity for amplifiers, pulse shaping circuits, etc., which are obligatory with other known counting devices.

Referring now to FIGURE 3 a device of the kind described is shown having drive and output arrangements. 314 are 20 electroluminescent elements as previously described, each having associated layers such as 111, 112, 113 and electrodes such as 115 of FIGURE 1, all carried round the periphery of a conducting base 310. Only the electroluminescent elements and top electrodes are shown.

Each electroluminescent element 314 and its associated top electrode extends radially inwards to cover one or other of two separate photoconductive layers 342 or 343. Layer 342 is of such a size as to be covered by part of one element 314 while photoconductive layer 343 is covered by part of the remaining 19 elements 314. Layers 342 and 343 are provided with overlying conducting transparent coatings to which connexions are made by conductors 344 and 345 respectively, and with a lower electrode 346 common to both layers 342 and

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343 and insulated from the base 310 to which a connexion 347 is made.

The parts of elements 314 which extend over layers 342 and 343 are provided with lower electrodes connected to the base 310, which lower electrodes are insulated from the upper electrodes of layers 342 and 343 by means of a transparent varnish.

As in the device shown in FIGURE 1 alternate top electrodes 315 are connected to two conductors 320 and 321 which are carried on the periphery of the base 310, these conductors providing the input connexions to the device, corresponding to 120 and 121.

Each alternate luminescent element is designated "0" . . . "9" as shown in FIGURE 3, and a small extension of the "0" luminescent element is provided as shown at 350, and this extension is provided with an upper electrode 351 to which is connected conductor 352.

The base 310 is connected by way of a load 348 with one side of an alternating current supply 350 the other side of which is connected by way of a normally closed switch 361 to the moving arm of a two-way switch 322. The poles of the switch are connected to the conductors 320 and 321 as shown. The lead 352 is connected to one pole of the supply 350 by way of a normally open switch 349 which is ganged to switch 361.

In FIGURE 4 two devices, 455 and 455', of the kind described in relation to FIGURE 3, each having 20 luminescent elements (some only of which are shown) are connected in series. The base 410 of each device is connected by way of a lead 448 to one side of a supply of alternating current 450. In the embodiment being described the supply was at a pressure of 230 volts at 400 cycles per second. The other side of the supply is connected to a switch 422 having two poles, one connected to each driving conductor 420 and 421 of the first device 455 and by way of a conductor 460 with the common side of the output electrodes of each device. It is further connected by way of a switch 449 and leads 452 to the electrodes 451 of each device. Switches 449 and 461 are ganged together. Output leads 444 and 445 from device 455 are connected to input leads 320 and 321' of device 455'.

In operation as a counter it is arranged that the events to be counted apply alternating potential alternately to leads 420 and 421 of device 455. This may be effected, as in FIGURE 4, by means of switch contacts. Many other means will be apparent. To start the count switch 449 is closed momentarily to excite the luminescent elements corresponding to 350 (FIG. 3) in each device. At the same time switch 461 opens to extinguish any luminescent element which may have been glowing. The excitation of element 450 renders conductive the photoconductive layer underlying the luminescent element designated "0" in each device and assuming that switch 422 is connected at first with the conductor corresponding to 320 (FIG. 3) the "0" element in each device will become excited. Now moving the switch 422 between 420 and 421 will step the glow round the elements, one element per switch movement, as previously described.

It will be seen that as the glow moves from luminous element "9" to "0" it passes through a blank element, and that operation of the switch 422 and 420 to 421 and back again is required for a count of one. As the glow moves round from element "0" to element "9" successive parts of output layer 443 are rendered conductive, which serve to keep element "0" of device 455' glowing, current flowing by way of 443, 445 and 420' to effect this.

When the glow in 455 moves from the "9" element to the blank element before "0" output layer 443 ceases to be conductive and layer 442 becomes conductive. Current now flows by way of 444 and 421' to step the glow in 455' from the "0" element to the next blank element and when the glow in 455 moves from the blank element between "9" and "0" on to the "0" element as a result

of a movement of switch 422 output layer 442 and 455 ceases to conduct and layer 443 again conducts so that an output signal by way of line 445 switches the glow in 455' to the "1" element. In this way the devices shown in FIGURE 4 will count to 99, and further orders could be provided by connexion of one or a series of further devices to the output connectors 444' and 445' of device 455'.

Obviously devices as described must either be operated in the dark, or in ambient light of a wavelength which does not cause the photoconductive layers to conduct. If a visual indication is required it is however quite possible to provide transparent layers 112 of one colour, e.g. red, and to provide the device with a further complementary filter above the electrode layers 115 of another colour (e.g. green) so that the superimposed filters stop ambient light from falling upon the layers 111, while luminescence in any of the layers 114 may be perceived through the filter. In such a case the electrodes 115 are of transparent conducting material, and where a visual read out is desired suitably apertured masks may be provided bearing characters through which the glow is visible.

As described, each device has 20 luminescent elements, and is thus a true scale of ten divider. When for any reason it is desired that each luminescent element should be an indicating or counting element it is possible to provide an intermediate device, having say four luminescent elements, to provide the required scale of two.

Of course the output layers must have a rapid rise time compared with the decay time of the photoconductive layers 111.

Where outputs are required from each position (i.e. when the devices are used as selectors) each luminescent element may be provided with a further separate photoconductive output layer.

Furthermore it will be apparent that it is possible to have more than one glowing luminescent layer in such devices at one time so that devices in accordance with the invention may be used to store patterns of signals and to provide shifting registers.

It is, of course, simple to provide a number of devices as described on one base, each device being connected to the next by means of printed or sprayed circuit connexions.

What is claimed is:

1. A counting device comprising a plurality of electro-optical pairs of photoconductive and electroluminescent elements disposed in order adjacent to each other, means for causing the electroluminescent element of the first pair to luminesce, the electroluminescent element of each of said pairs except the last pair being adapted when luminescent to illuminate both the photoconductive element of said pair and at least part of the photoconductive element of the next pair, means for deriving an output signal, from the last pair, and means for switching the input signals between alternate pairs.

2. A counting device comprising a plurality of electro-optical pairs of photoconductive and electroluminescent elements disposed in order adjacent to each other, each of said electroluminescent elements being adapted when excited to illuminate and render conductive part of each of two adjacent photoconductive elements, each of said photoconductive elements being adapted when conductive to complete the exciting circuit of one of said electroluminescent elements, alternate electroluminescent elements being connected together to provide two sets of such elements, a source of alternating current potential, and switching means for connecting said sets of electroluminescent elements alternately to said source.

3. A counting device according to claim 2 wherein said electro-optical pairs are arranged in a closed ring and so disposed that the electroluminescent element of the last pair is adapted when excited to illuminate and render conductive at least part of the photoconductive element of the first pair.

4. A counting device according to claim 2 wherein each of said photoconductive elements is adapted to be illuminated by two adjacent electroluminescent elements, and which includes transparent layers of conductive and insulating material for electrically connecting and electrically insulating corresponding parts of each of said photoconductive elements to and from the adjacent electroluminescent elements respectively.

5. A stepping or counting device of the character described comprising two chains of electro-optical pairs of photoconductive and electroluminescent elements so arranged that the pairs of each chain are connected in parallel with one another and each pair of each chain is positioned adjacent a pair of the other chain, a source of alternating current potential, and means for connecting said chains alternately to said source.

6. A stepping or counting device as claimed in claim 5 wherein said electro-optical pairs are arranged in order and so disposed that the electroluminescent element of each of said pairs except the last pair is adapted when excited to illuminate and render conductive both the photoconductive element of said pair and at least part of the photoconductive element of the next pair, and which includes means for exciting the electroluminescent element of the first pair.

7. A stepping or counting device as claimed in claim 5 wherein all of said photoconductive elements lie in a common plane and all of said electroluminescent elements lie in another plane substantially parallel to the plane of said photoconductive elements.

8. A stepping or counting device as claimed in claim 5 wherein said electro-optical pairs are arranged in a closed ring and so disposed that the electroluminescent element of the last pair is adapted when excited to illuminate and render conductive at least part of the photoconductive element of the first pair.

9. A stepping or counting device as claimed in claim 5 wherein said electro-optical pairs are arranged in a closed ring with the photoconductive and electroluminescent elements of each pair in partially offset relationship such that each electroluminescent element overlaps parts of two adjacent photoconductive elements and each photoconductive element overlaps parts of two adjacent electroluminescent elements.

10. A stepping or counting device as claimed in claim 9 including a transparent layer of conductive material interposed between the photoconductive and electroluminescent elements of each of said pairs and extending over a portion of the photoconductive element of an adjacent pair, and a transparent layer of insulating material between each of said layers of conductive material and the underlying portion of said adjacent photoconductive element.

11. A stepping or counting device of the character described comprising two chains of electro-optical pairs in photoconductive and electroluminescent elements arranged in a closed ring with the pairs of each chain connected in parallel with one another and each pair of each chain positioned between two pairs of the other chain, a source of alternating current potential, means for alternately connecting said chains to said source so as to cause step-by-step excitation of the electroluminescent elements in sequence around the ring, and means for producing an output signal whenever a preselected one of said electroluminescent elements is excited.

12. A stepping or counting device as claimed in claim 11 wherein the means for producing an output signal includes an output photoconductive element so disposed as to be illuminated by said preselected electroluminescent element when the latter is excited.

13. A stepping or counting device of the character described comprising two chains of electro-optical units so arranged that each unit of each chain is positioned adjacent a unit of the other chain, each of said units including a pair of electrodes between which are disposed a

photo-conductive element, an electroluminescent element and a transparent layer of conductive material between said photoconductive and electroluminescent elements, a source of alternating current potential to which one of the electrodes of each of said units is permanently connected, and means including a switching device for connecting the other electrodes of all units in each chain to said source in parallel alternately with the other electrodes of all units in the other chain.

14. A stepping or counting device as claimed in claim 13 wherein the electroluminescent element and layer of conductive material of each unit overlap parts of the photoconductive element and layer of conductive material of an adjacent unit, and which includes a transparent layer of insulating material between the overlapping portions of adjacent layers of conductive material.

15. A stepping or counting device as claimed in claim 13 including a starting electrode associated with the electroluminescent element of one of said units, and means for momentarily connecting said starting electrode to said source of alternating current potential to excite the associated electroluminescent element and simultaneously opening the connection between said source and said switching device.

16. A counting device of the character described comprising two chains of electro-optical units arranged in a closed ring with one unit of each chain positioned between two units of the other chain, each of said units including a pair of electrodes between which are disposed a photoconductive element, an electroluminescent element and a transparent layer of conductive material between said photoconductive and electroluminescent elements, a source of alternating current potential to which one of the electrodes of each of said units is permanently connected, switching means for connecting the other electrodes of all units in each chain to said source in parallel alternately with the other electrodes of all units in the other chain, an output circuit, a first supplemental photoconductive element disposed between a pair of supplemental electrodes and so positioned as to be illuminated by the electroluminescent element of a preselected one of said units when said electroluminescent element is excited, and a second supplemental photoconductive element disposed between a pair of supplemental electrodes and so positioned as to be illuminated whenever the electroluminescent element of any unit other than said preselected unit is excited, one of the supplemental elec-

trodes associated with each of said supplemental photoconductive elements being normally connected to said source of alternating current potential, and the other supplemental electrode associated with each of said supplemental photoconductive elements being connected to said output circuit.

17. A counting apparatus comprising two counting devices as claimed in claim 16 connected in series with the output circuit of the first device serving as the switching means of said second device.

18. A stepping or counting device of the character described comprising a conductive base plate, a plurality of photoconductive elements mounted on said base plate in laterally spaced relationship, a transparent layer of conductive material overlying each of said photoconductive elements and part of an adjacent photoconductive element, a transparent layer of insulating material interposed between the overlapping portions of adjacent layers of conductive material, a plurality of electroluminescent elements equal in number to said photoconductive elements and each overlying parts of two adjacent photoconductive elements, a layer of conductive material superimposed on each of said electroluminescent elements, a switching device having two output terminals each of which is connected to alternate ones of said last-named layers of conductive material, and a source of alternating current potential connected to said conductive base plate and to the input terminal of said switching device, said switching device being operable to connect the output terminals thereof alternately to said source so as to cause step-by-step excitation of said electroluminescent elements.

19. A stepping or counting device as claimed in claim 18 wherein said photoconductive elements and said electroluminescent elements are arranged in a closed ring with all of said photoconductive elements lying in a common plane and all of said electroluminescent elements lying in a second plane substantially parallel to the plane of said photoconductive elements.

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