April 2, 1968 K. P. LALLY 3,376,452

CIRCULAR ELECTROLUMINESCENT DISPLAY DEVICE

Filed Nov. 9, 1964 2 Sheets-Sheet 1

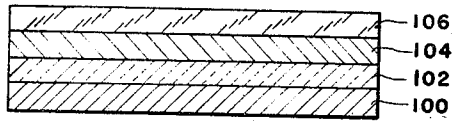



FIG. 1

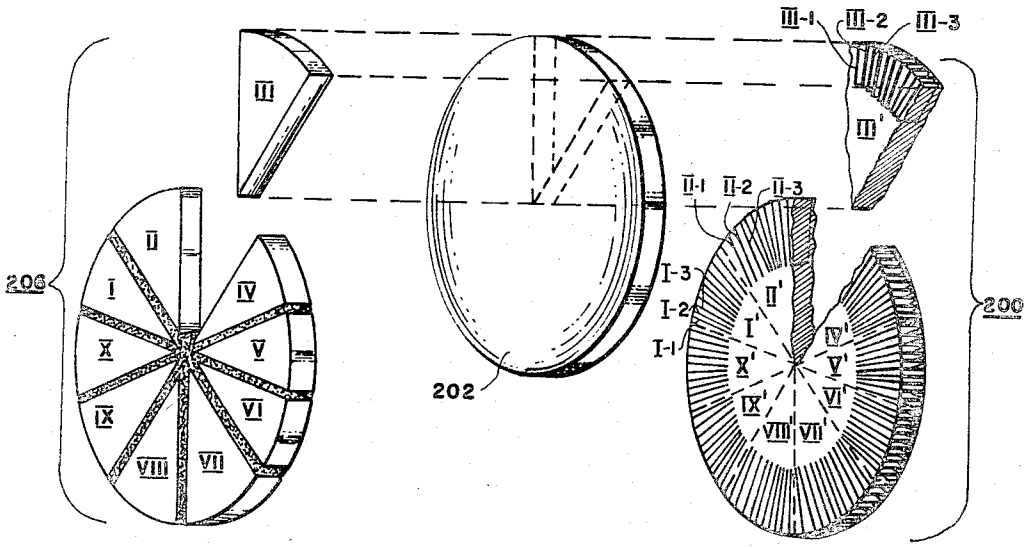



FIG. 2

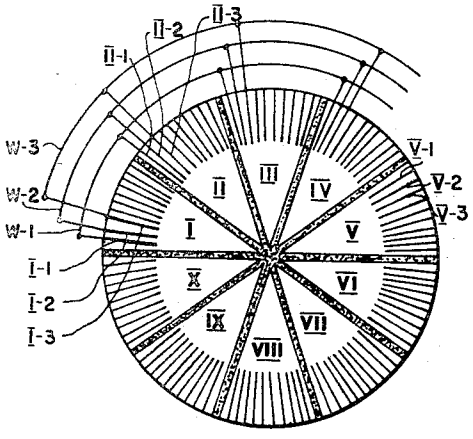



FIG. 4

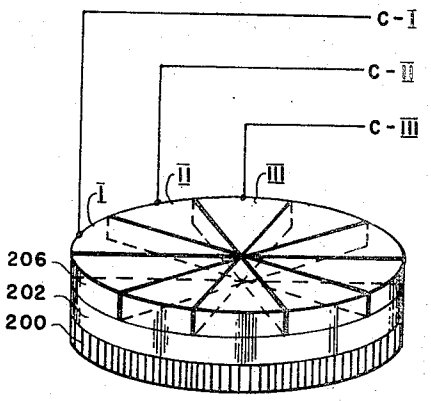



FIG. 5

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CIRCULAR ELECTROLUMINESCENT DISPLAY DEVICE

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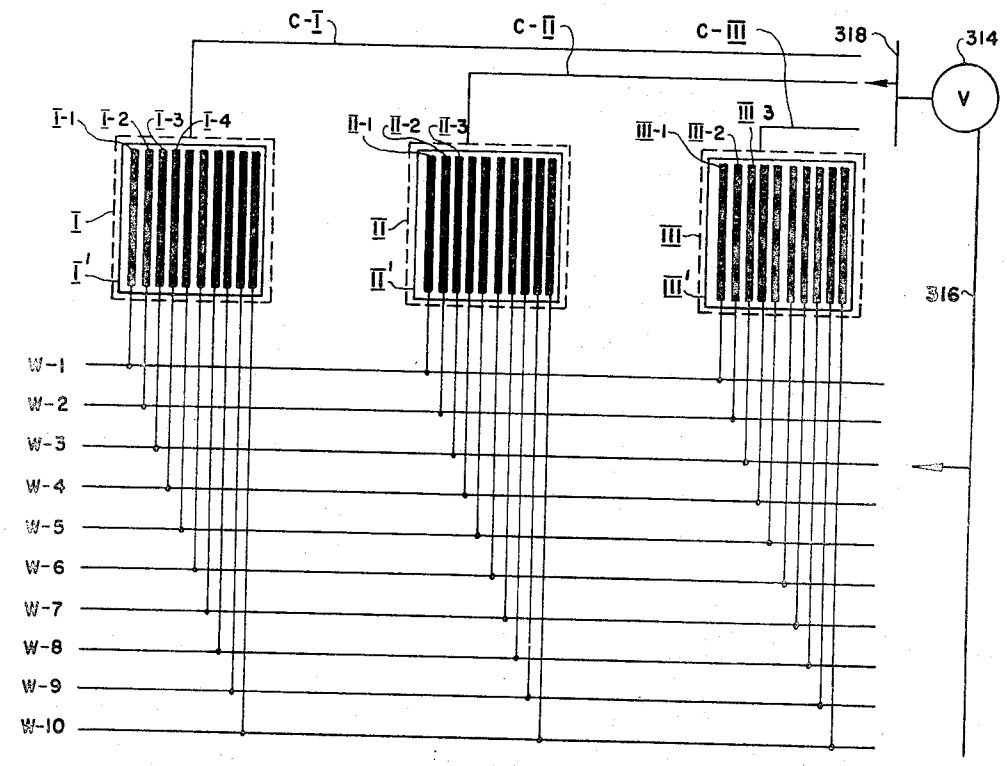



FIG. 3

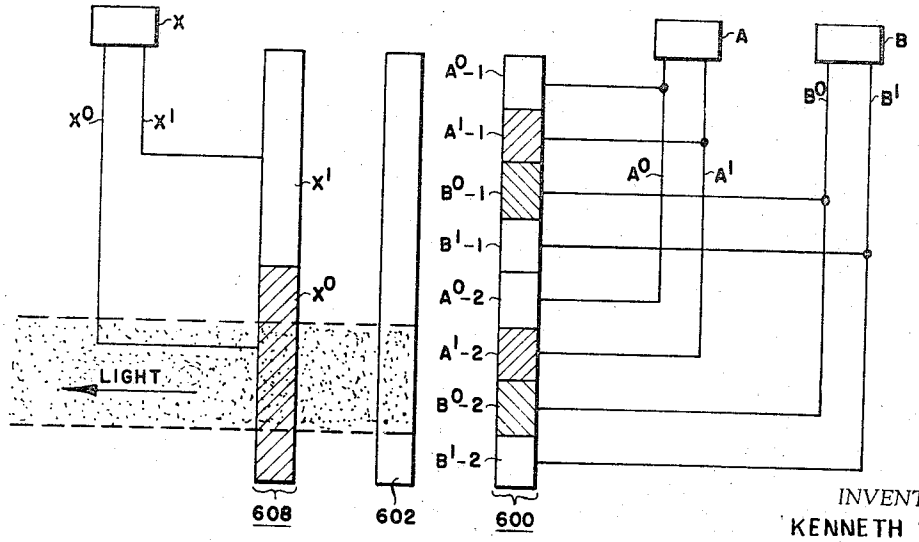



FIG. 6

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United States Patent Office 3,376,452
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3,376,452

# CIRCULAR ELECTROLUMINESCENT DISPLAY DEVICE

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4 Claims. (Cl. 313—108)

This invention relates to improved display devices and, more particularly, to ones involving the excitation of electro-luminescent materials.

It is well-known that there are certain materials which will glow and emit light when subjected to electrical excitation. Such materials include, but are not limited to, zinc sulfide and/or zinc oxide, or cadmium sulfide properly activated by the addition of small amounts of some other material, such as copper, lead manganese, or silver. Such electroluminescent materials may be disbursed in some light transmitting dielectric material, such as plastic, or resin, and are thereby rendered into a form which is structurally sound and facilitates handling and fabrication.

Electrical excitation of such an electroluminescent material may be accomplished by the use of almost any electrically conductive material, formed into shapes such as sheets, strips, or even distinctive configurations. By positioning such conductors on both sides of electroluminescent material of the type heretofore described and electrically energizing the conductors, that portion of the electroluminescent material lying between the conductors can be caused to luminesce due to the potential difference existing between the conductors.

Viewing the glow generated thereby is usually achieved by having at least one of the condutcing electrodes translucent. This may be accomplished by depositing an extremely thin film of conductive material, such as cadmium oxide or tin oxide, over one surface of some transparent, or at least translucent material such as glass. Such an electrode will transmit electrical energy and, being light transmissive, will permit the glow of the luminescing material to be seen at the same time.

By use of such principles, devices have been made which offer many advantages over conventional meters and other types of display devices. Electroluminescent display devices are optically active, rather than passive. Paralax problems may be avoided since it is possible to incorporate into the structures themselves reference scales which are substantially co-planar with either of the electrode layers or with the electroluminescent layer. Being comparatively thin and flat, electroluminescent display devices save space, and are easily integrated into arrays of other instruments. Electroluminescent devices have no moving parts to wear or be serviced. They are not subject to total failure from damage to a portion of the structure. They do not require calibration, since they are responsively linear, and do not have the mechanical or electrical hysterisis characteristics inherent in most display devices of other types. They are susceptible to being constructed in a wide variety of geometrical configurations.

Until now, however, where such electroluminescent devices have been used for display purposes, for example, as read out devices in conjunction with number systems, they have merely been aggregations or groupings of several simple electroluminescent devices substantially of the type heretofore described. Thus, a given number might be indicated by activation of one or more of the several electroluminescent devices comprising the group, producing a display in which the number in question was identified by the distinctive shape or position of the device



energized, or by shape or position of the cumulative total of luminescence produced by energization of several of the component devices.

Such displays have several disadvantages which have greatly restricted applicability of the electroluminescent display devices to a wide variety of applications. The associated circuitry required is extensive, since each of the devices forming the whole display must be energized as an entity, distinct from all the others in the grouping. Furthermore, until now an analog display of digital inputs required the use of a digital-analog converter which, in itself, adds to the complexity of the associated circuits.

It is an object of this invention to utilize electroluminescent devices for display purposes which achieve the recognized features of such devices, yet are structurally and electrically simple.

Another object of this invention is to reduce the number and complexity of electrical circuits necessary to energize all the electrodes of an electroluminescent display device.

Yet another object of this invention is to permit analog displays of digital inputs without the necessity of using analog to digital converters.

Still another object of this invention is to provide a display device which is capable of accepting and communicating repetitive digital inputs.

These and other objects are achieved through use of this invention in which groups of electrodes forming a first electrode layer in an electroluminescent device, the component electrodes of which have been suitably electrically interconnected in the manner hereafter described, are positioned on the opposite side of the layer of electroluminescent material from several electrodes forming the other electrode layer of the device, each one of which overlays one of the groups of electrodes in the first electrode layer.

This invention may be understood by referring to the discussion which follows and to the attached drawings in which:

FIGURE 1 is a cross-section view of a typical electroluminescent display device,

FIGURE 2 is an exploded isometric view of one embodiment of this invention,

FIGURE 3 is a circuit diagram of the embodiment of this invention shown in FIGURE 2,

FIGURE 4 is a plan view of the embodiment of this invention shown in FIGURE 2,

FIGURE 5 is an isometric view of the embodiment of this invention shown in FIGURES 2 and 4, and

FIGURE 6 is a view of another embodiment of this invention.

Referring first to FIGURE 1, depicted therein is a cross-section of a typical electroluminescent device. It comprises a lower electrode **100** made from any suitable conductive material, an electroluminescent layer **102**, and an upper transparent electrode **106**; all of which may be made in the manner heretofore described. In addition, a layer **104** of material which is non-linearly resistive may be interposed between the upper electrode **106** and the electroluminescent layer **102**, but the presence of such a layer is not essential to practicing this invention. The purpose of such a non-linearly resistive layer when present is to heighten the contrast between those portions of the device from which it is desired to have light emitted and those from which it is not. The output glow of the device normally is read through the upper transparent electrode **106**. Electrical energy may be supplied to the electrodes **100**, **106** by means of insulated conductors electrically connected to connecting terminals (not shown) formed as part of the electrodes so as to cause the potential between the electrodes to be adequate to cause the electroluminescent material to glow. In addition, "substrates"

(not shown), such as sheets of glass or other suitable light transmissive material, may optionally be positioned about the device in order to protect it while, at the same time, permitting emitted light to be observed, although their use is not essential to practicing this invention.

FIGURE 2 illustrates an embodiment of an electroluminescent device involving the structural and operational characteristics of electroluminescent devices of the type set forth in FIGURE 1 insofar as they relate to the practice of this invention. Depicted in FIGURE 2 is an electroluminescent display device having a front transparent electrode layer **206**, a back electrode layer **200**, and, interposed therebetween, a layer of electroluminescent material **202**. In their normal attitudes, these three layers are positioned so that the electrode layers **206, 200** are in contact with each side respectively of the electroluminescent layer **202**, with the peripheral surfaces of the three layers contiguous. However, these components are shown in FIGURE 2 separated from each other so that their individual characteristics may be observed, and with the electroluminescent layer **202** axially offset from the electrode layers **206, 200** so that their normal overlaying positional relationship may be demonstrated and elaborated upon in the discussion which follows. Furthermore, in order to facilitate discussion, structural elements, such as a non-linearly resistive layer, substrates, etc. which may be used in connection with such an embodiment but are not vital to this invention, are not shown.

In the embodiment shown in FIGURE 2, the front electrode layer **206** consists of a group of sector shaped translucent electrodes I, II, III . . . etc., each of which is electrically discrete from all of the others. In FIGURE 2, ten such sector shaped electrodes, each of 36° angular sweep, are shown.

The back electrode **200** includes a multitude of linear electrodes **I–1, I–2, I–3, I–4** . . . etc., **II–1, II–2, II–3, II–4** . . . etc., **III–1, III–2, III–3, III–4** . . . etc., **IV–1, IV–2, IV–3, IV–4** . . . etc., . . . etc. which are radially arrayed with one end of each such electrode at the peripheral edge of the back electrode layer **200** and the other end of each such electrode positioned toward, but stopping well short of, the center of the back electrode layer **200**. These linear electrodes are electrically discrete from each other and each is spaced apart from the ones on either side of it at a distance such that an equal number of them are overlayed by each of the sector electrodes I, II, III . . . etc. in the front electrode layer **206**. By this means, there are respectively delineated groupings I′, II′, III′ . . . etc. of the linear electrodes **I–1, I–2, I–3** . . . etc., **II–1, II–2, II–3** . . . etc., **III–1, III–2, III–3** . . . etc., . . . etc. in the back layer **200**; all of the linear electrodes in a given group being electrically opposed by one, sector shaped, translucent electrode in the front layer **206**. Thus, linear electrodes **I–1, I–2, I–3** . . . **I–10** form group I′ of the electrode layer **200**, and this group I′ is electrically opposite the sector shaped electrode I in layer **206**.

Similarly, electrodes **II–1, II–2, II–3** . . . **II–10** form group II′ which is opposed electrically by sector electrode II, electrodes **III–1, III–2, III–3** . . . **III–10** form group III′ opposite sector electrode III, etc. In the embodiment illustrated in FIGURE 2, ten such linear electrodes form each of the groups and there are ten such groups in the back electrode layer **200**, so that there is one group for each corresponding sector electrode in the front electrode layer **206**.

Referring now to FIGURE 3, shown therein is a typical circuit diagram for the embodiment of this invention which is illustrated in FIGURE 2. In FIGURE 3, an electrical power source **314** is electrically interconnected with switching means **316, 318** of any of a number of widely recognized designs which are suitable for selectively connecting the conducting path from the power source **114** to any one of a number of other conducting paths.



For purposes of illustration, in FIGURE 3 the translucent sector electrodes I, II, III of the front electrode layer and the corresponding electrode groups I′, II′, III′, of the back electrode layer correspond in their relationship to each other to electrodes I, II, III of layer **206** and electrode groups I′, II′, III′ of layer **200** in FIGURE 2, but in FIGURE 3 electrodes I, II, III are shown as squares rather than as sectors of a circle, and the linear electrodes **I–1, I–2, I–3** . . . etc., **II–1, II–2, II–3** . . . etc., **III–1, III–2, III–3** . . . etc. are shown in parallel array rather than in the fan shaped array they would normally occupy in a sector shaped grouping. It will be noted that each of the transparent electrodes I, II, III is electrically discrete from all the others and that these electrodes are connected to the selector switch **318** by separate circuits C–I, C–II, C–III respectively. It will also be noted that each linear electrode in each of the electrode groups I′, II′, III′, is electrically common to those linear electrodes in all of the other groups which occupy the same sequential position in their respective groups as it does. Thus electrode **I–1** in group I′, electrode **II–1** in group II′, and electrode **III–1** in group III′, as well as every other first electrode (not shown) in all of the electrode groups (not shown) in the same layer are connected to the same conducting path **W–1**, which interconnects with one discrete position on the selector switch **316**. Similarly, electrodes **I–2, II–2, III–2** in groups I′, II′, and III′ respectively are all electrically common with each other and the second electrode in every other group in the same electrode layer, and all such electrodes are electrically interconnected with another discrete position on the selector switch **316** by means of a common conductor **W–2**. This arrangement is carried out for all of the other linear electrodes in each group with all of the corresponding electrodes in each of the other groups.

FIGURE 4 is a plan view of the embodiment of this invention which has been discussed, showing the circuitry heretofore described with reference to the linear electrodes of FIGURE 3 as they would actually be interconnected in the configuration shown in FIGURE 2. Similarly, FIGURE 5 shows the circuitry which has heretofore been described with reference to the sector electrodes of FIGURE 3 as they would actually be connected in this same embodiment as shown in FIGURE 2.

The operation of the embodiment of this invention which has heretofore been described will now be discussed, referring to FIGURES 3, 4 and 5 at the same time. A digital counter (not shown), of any of a number of well-known designs which would be suitable for the intended use, is interconnected with the positional selector of the selector switch **316**, thereby imparting a means whereby the switch will be positioned so as to make a connection between the power source **314** and that circuit corresponding to the digit recorded, e.g. circuit **W–1** for the unit **1**, Circuit **W–7** for the unit **7**, etc. Similarly, a "tens" counter of suitable design is interconnected with the positional selector **318** so that a connection will be made between the power source and that circuit which is distinctive to the "tens" group being recorded, e.g. circuit C–I for one accumulation of ten, circuit C–III for three accumulations of ten. Assume for purposes of discussion, that a total of 23 has been counted; 2 accumulations of 10 (or 20) on the "tens" counter, and 3 on the units counter. As shown by the location of the arrows representing the selected positions on the selector switch **316, 318** in FIGURE 3, circuits **W–3** and **C–II** will be electrically energized. All of the linear electrodes which are electrically connected to circuit **W–3** will be energized, and those consist of the third sequential electrode in every electrode group, i.e. electrodes **I–3, II–3, III–3** . . . etc. However, firing of the electroluminescent layer so as to cause it to glow requires that electrical potential be applied across it. Therefore, only that portion of the electroluminescent layer **202** will glow which is between one of the energized linear electrodes in layer **200** and an energized sector

electrode in layer **206**. Thus, a readily discernible band of luminescence will occur only between linear electrode II–3 and sector electrode II, and, since none of the other sector electrodes are energized, this electroluminesce band will stand out in marked contrast to other positions on the display device. As may be seen by referring to FIGURE 4, the glow which does occur will be in the form of a radially oriented line positioned with one of its ends at the edge of the display device and will have a distinctive positional location at the third incremental position under sector electrode II. No other combination of units and "tens" counter outputs will cause luminescence at this location, and this combination of counter outputs will not cause luminescence at any other location. Similarly, each different combination of counter outputs will cause a distinctively located display peculiar to that combination only.

It will be obvious to those skilled in the art that electroluminescent display devices utilizing the principals of this invention achieve all of the advantages which have heretofore been cited as making it desirable to use electroluminescent devices, and, in addition, make it possible to do so with less extensive and complex circuitry or circuit components. In the embodiment discussed herein, for example, displays of up to 100 discrete values may be made through the use of 20 energizing circuits instead of the 101 circuits which would have been the minimum number required for operation of an electroluminescent device of the type heretofore known. Obviously, similar reductions in the number of circuits necessary to achieve a given range of display are possible by utilization of this invention, regardless of the number of electrodes in a given group, or the number of groups in a given display. Thus, even if, in the embodiment heretofore described, 20 sector electrodes formed the front electrode layer and 5 electrodes formed each group in the back electrode layer instead of the 10 and 10 combination which has been described, and if the sector inputs were "fives" and the group electrode inputs were still digits, only 25 conductive paths would be needed to energize every position in the display. Furthermore, it will be seen that the greater the number of outputs to be displayed, the greater will be the advantage realized in terms of the amount of circuitry necessary to effect the display. Thus, in the "10 over 10" embodiment already discussed herein, 10 overlays of 10 each required a total of 20 circuits to produce 100 read outs. But by merely adding units so that there are, for example, 100 overlays of 10 each, only 110 (or about 5 times as many) circuits could produce 1000 (or about 10 times as many) read outs. Even greater savings in the amount of circuitry required may be achieved where the number of electrodes comprising both the groups and the overlaying layer are increased simultaneously. Thus 32 overlays of groups having 32 electrodes each will have a display capacity of 1024 outputs with a total of only 64 input circuits. Furthermore, where analog instead of digital readouts are desired, digital to analog conversion of input signals is unnecessary because devices may be constructed in accordance with this invention so as to display outputs which may be given analog interpretation without the necessity of a digital to analog conversion operation. Thus, in the embodiment heretofore discussed, digital inputs can be made to display analog values by appropriately orienting the component electrodes with respect to some reference standard such as a dial, or scale. Since this is so, it is unnecessary to incorporate into the circuit separate means for converting digital inputs to analog outputs. It is also apparent that, through practicing this invention, readout displays may be made of repeating series of numbers as well as of steady state values.

It will also be obvious that the teaching which has been set forth herein may be practiced in a wide variety of embodiments without departing materially from the principles of this invention.



For example, it is possible to utilize this invention to make a gating matrix such as that illustrated in FIGURE 6. Depicted therein is a pair of primary gates A, B, each of which is capable of discriminating two states, equivalent to "go" and "no go" respectively. Each such state is sequentially connected to one electrode in every group comprising the back electrode layer **600**. Thus, the "go" state of A gate energizes circuit A', which, in turn, energizes electrode A'–**1**, and electrode A'–**2**. The "no go" state of gate A energizes circuit $A^0$ which, in turn, energizes electrodes $A^0$–**1** and $A^0$–**2**. An analogous relationship exists as to gate B and its associated electrodes.

Secondary gate X is also capable of discriminating two states, so that when it is in "go" status, circuit X' is energized, as is its associated electrode X' in the front electrode layer **608**. Similarly, its "no go" state energizes electrode $X^0$.

Assume, for purposes of illustration that primary gates A, B are in "go" and "no go" states respectively, causing electrode A'–**1** and A'–**2** and $B^0$–**1** and $B^0$–**2** respectively to be energized. Assume also that secondary gate X is in a "no go" state, causing electrode $X^0$ to be energized. Electroluminescent material **602** interposed between the electrode layers **600**, **608** will be caused to glow only in those regions where the bracketing electrodes are energized or, in the states described, between electrodes $X^0$, and electrodes A'–**2** and $B^0$–**2**, and then only insofar as electrode $X^0$ is coextensive with electrodes A'–**2** and $B^0$–**2**. The light emitted will be uniquely positioned for this state of the gates, and this state of the gates will produce no other output. Obviously, gates having more states than two may be so monitored, provided there are as many interconnected electrodes for each state of each primary gate as the total number of states for all of the secondary gates, and provided further that there are no more than two gating layers in the matrix.

It will also be obvious that the teaching which has been set forth herein may be accommodated not only to a wide variety of uses, but in many different forms structurally.

By way of illustration but not of limitation, the electrodes may be formed in any of a wide variety of configurations, including parallel arrays of linear electrodes overlayed by rectangular or square electrodes, or with the electrodes in one of the groups interconnected with those in other groups in other than sequential order, or in any of a wide variety of numerical ratios of group electrodes to overlaying electrodes, or with either or both of the electrode layers light transmissive, or with the voltage responsiveness of a given pair of electrodes which are electrically opposed across a layer of electroluminescent layer made different from that of the other pair associated with it, by varying, vertically or laterally, the distance between given pairs of electrodes.

What is claimed is:

**1.** An electroluminescent display device comprising

a first circular electrode layer having at least one planar surface and having N number of electrically discrete sector shaped electrodes, each of which has a sector angle of 360/N degrees.

a second circular electrode layer having at least one planar surface, and having N number of groups of electrodes, each such group having more than two radially arrayed electrodes positioned within a portion of said second electrode layer which is sector shaped with a sector angle of 360/N degrees, and all such groups having the same number of electrodes, all such electrodes in a given group being electrically discrete from each other but electrically connected to one only of the electrodes in each of the other groups,

said first and said second electrode layers each having a planar surface in contact with the opposite sides of the same layer of electroluminescent material throughout the total extent of said surface,

the electrode in at least one of said electrode layers being translucent.

2. An electroluminescent display device comprising

a first round flat electrode layer having ten electrically discrete sector shaped transluscent electrodes of 36° each, each sequentially electrically connected to the output of a counter device capable of discriminating numbers in the order of $10^{n+1}$,

a round flat layer of electroluminescent material which is substantially coextensive with, in parallel planar relationship to, and positioned next to said first electrode layer,

and a second round flat lower electrode layer substantially coextensive with and in parallel planar relationship to said first translucent electrode on the side of said layer of electroluminescent material opposite said first electrode layer, said second electrode layer comprising ten groups of ten radially arrayed linear electrodes each, the electrodes of each such group being positioned so that each group occupies substantially all of that portion of said second electrode layer described on it by the projection of one of said electrodes in said first electrode layer, each linear electrode in each group being electrically interconnected with that electrode in each of the other groups which occupies the same sequential position as it does with respect to the remaining electrodes in its respective group, each of the ten sets of ten electrodes so electrically interconnected being sequentially connected to the output of a counter device capable of discriminating numbers in the order of $10^n$.

3. An electroluminscent display device comprising

a first planar electrode array having more than one electrode shaped as a sector of a circle, none of which are electrically connected to each other,

a second planar electrode array disposed in parallel planar relationship to said first electrode array and having the same number of groups of linearly shaped, radially arrayed electrodes as there are electrodes in said first electrode array, each of said groups having the same number of electrodes as there are electrodes in said first electrode array and all of said groups having the same number of electrodes, none of the electrodes in each group being electrically connected to each other, each electrode in each group being electrically connected to one of the electrodes in each of the other of said groups, each of said groups of electrodes in said second electrode array being paired with one of said electrodes in said first electrode array and lying within limits described by projecting the image of its associated electrode in said first electrode array through the shortest possible distance onto the second electrode array with electroluminescent material positioned therebetween,

the luminescent response of said electroluminescent material to energization of each of said electrodes in said second electrode array being different from the luminescent response of said electroluminescent material to energization to any of the other of said electrodes in said second electrode array,

the electrodes forming at least one of said electrode arrays being translucent.



4. An electroluminescent display device comprising

a first planar electrode array of circular configuration having N number electrodes which describe a sector of a circle and which are not electrically connected to each other,

a second planar electrode array of circular configuration and substantially equal in diameter to said first electrode array and disposed in parallel planar relationship thereto and having N number groups of linearly shaped, radially arrayed electrodes, each group having N number electrodes which are not electrically connected to each other, each of said electrodes in each of said groups in said second electrode array being electrically connected to that electrode in each other group which occupies the same sequential position in that group, each of said groups of electrodes in said second electrode array lying within the limits described by projecting the outline of one of said electrodes in said first electrode array onto the plane of said second electrode array,

and electroluminescent material positioned between said electrodes in said first electrode array and said electrodes in said second electrode array, the luminescent response of said electroluminescent material to energization of each of said electrodes in said groups in said second electrode array being different from the luminescent response of said electroluminescent material to energization of any of the other of said electrodes,

either said electrodes in said first electrode array, or said electrodes in said second electrode array being translucent.

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