

[54] **SOLID STATE ELECTROLUMINESCENT
X-Y DISPLAY PANELS**

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[51] Int. Cl. **H05b 37/00**

[58] Field of Search **313/108 B;
315/169 R, 169 TV; 340/166 EL**

[56] **References Cited**

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[57] **ABSTRACT**

One or more EL electrodes in the form of wire mesh

strips coated with electroluminescent phosphor are sandwiched between a rigid, transparent cover and a sheet of dielectric insulation. This panel is removably secured above a printed circuit board which carries a plurality of metal electrode strips that extend transversely to the EL electrode or electrodes. A plurality of spaced, non-linear electrical elements are secured between the panel and board to register with, for example, points where the EL electrode(s) intersect the printed circuit electrodes. In one embodiment, when an AC or pulsating voltage is applied across a selected EL electrode and an intersecting circuit board electrode, the non-linear element at the intersection of these electrodes conducts and causes the phosphor coating on the registering portion of the energized EL electrode to glow with a regulated intensity. If the non-linear elements are SCR's, the conduction of each SCR may be controlled by a pair of triggering signals arranged to be applied selectively as an X and Y coordinate, respectively, for each SCR. One or more spots, each registering with one of the non-linear elements, may thus be made to glow at selected points on the face of the panel, and with different colors, if desired.

22 Claims, 16 Drawing Figures

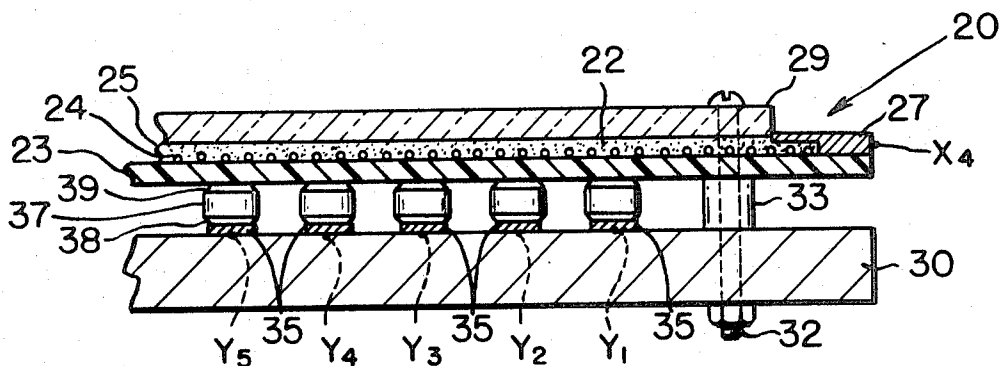


FIG. 4

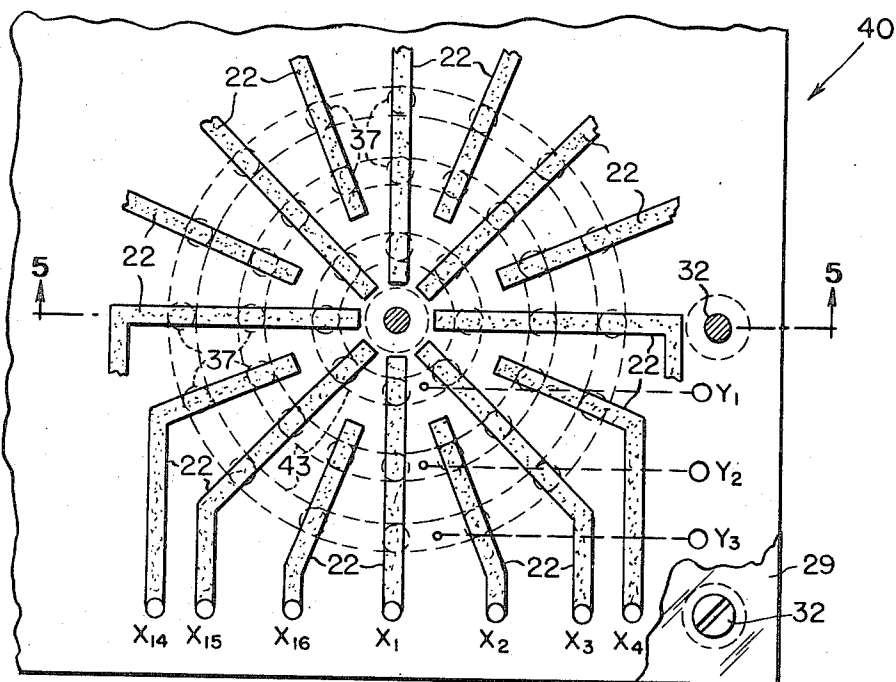


FIG. 5

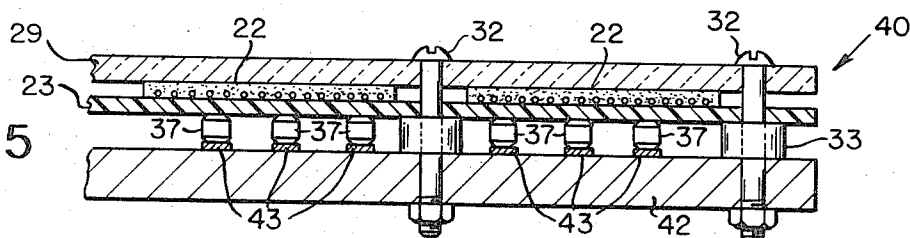


FIG. 6

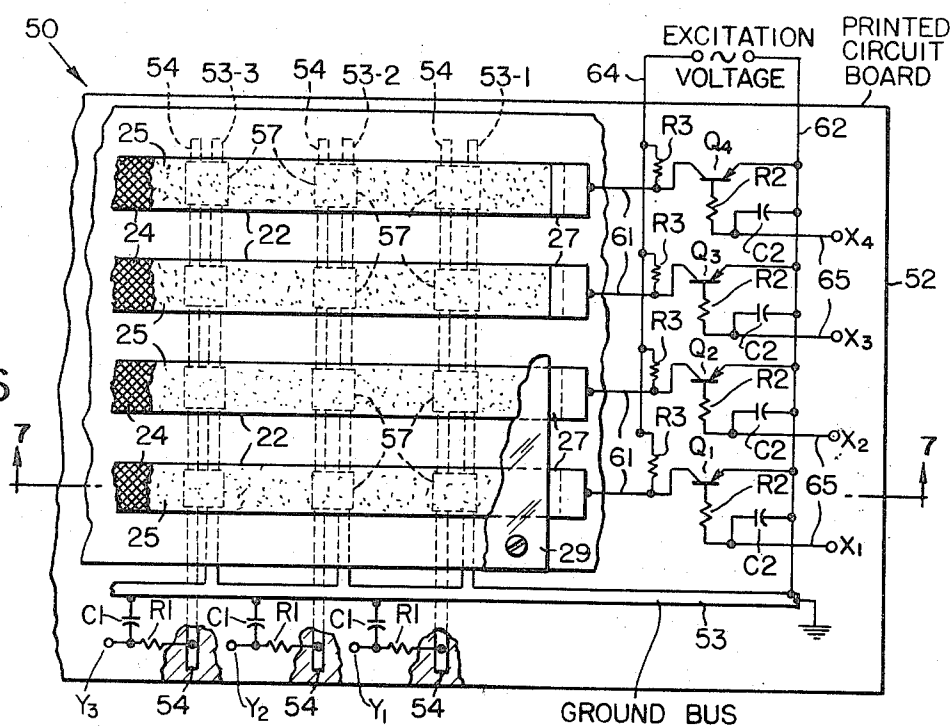


FIG. 7

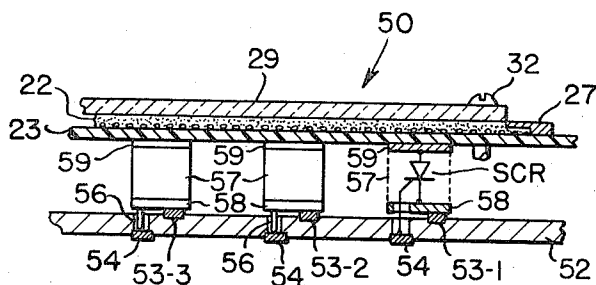
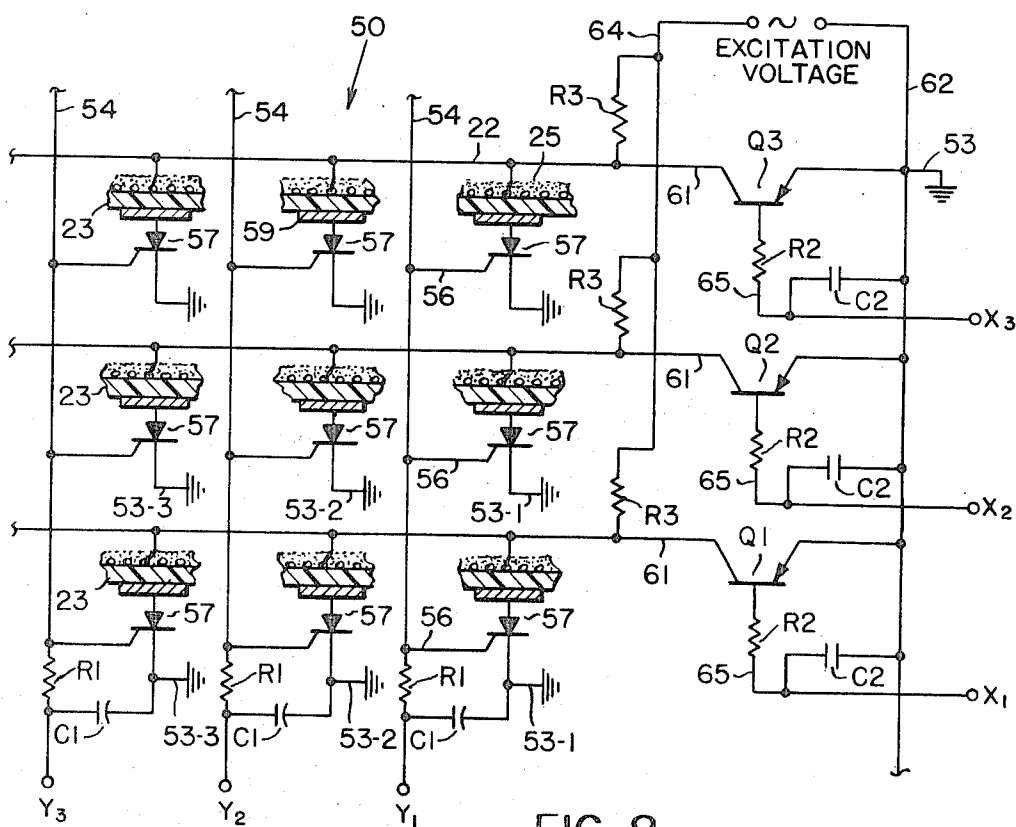


FIG. 8

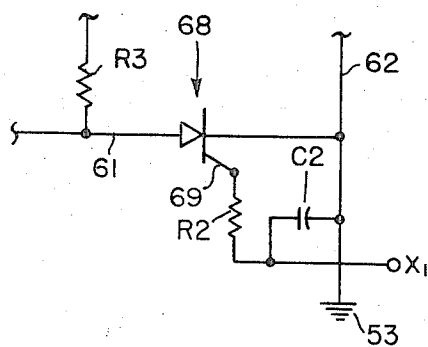


FIG. 9

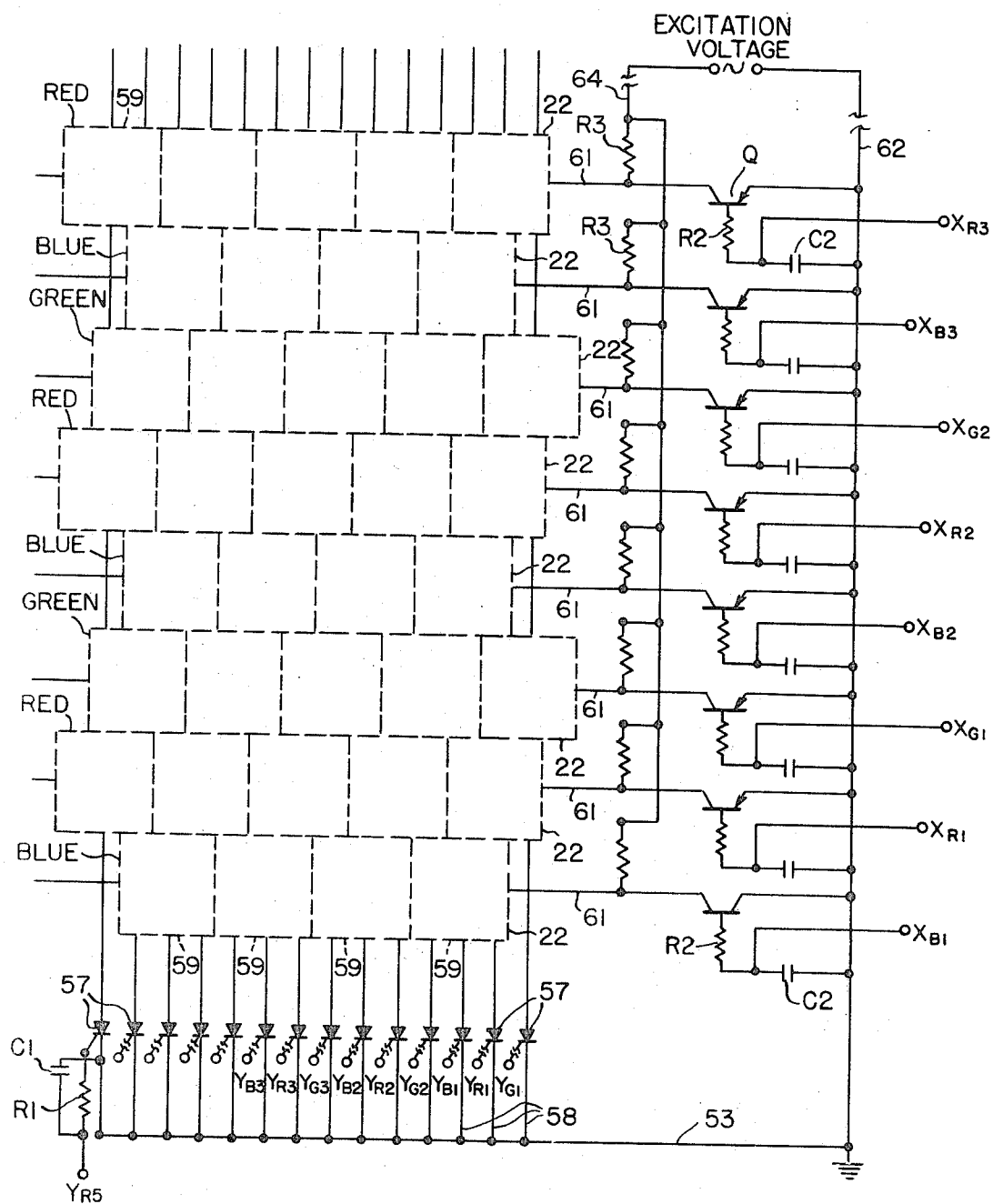
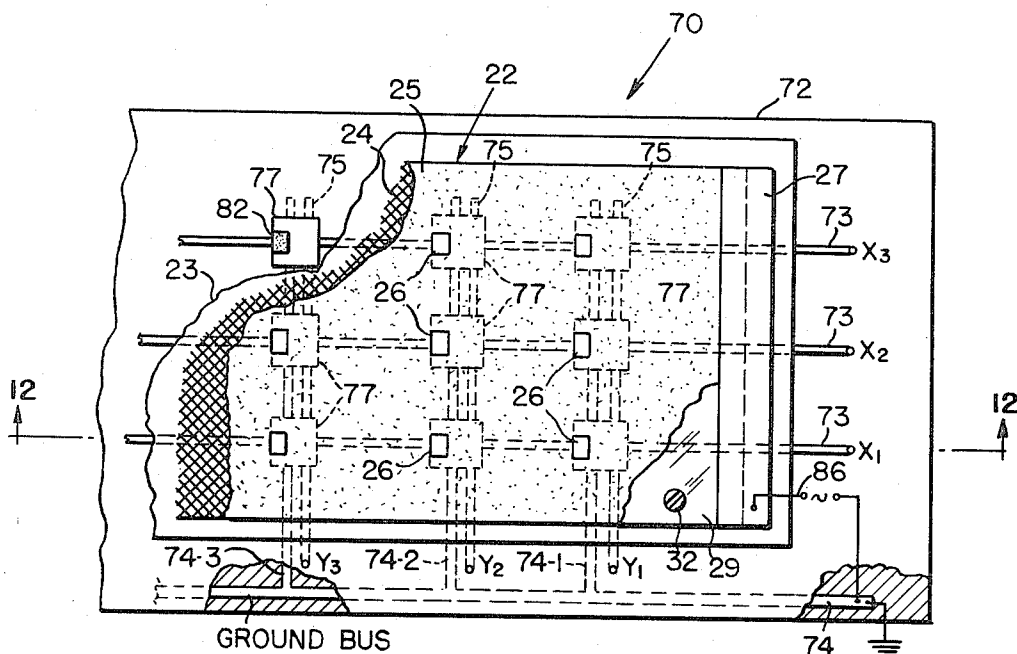
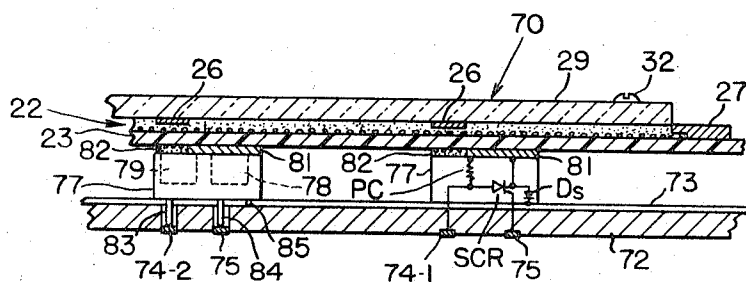
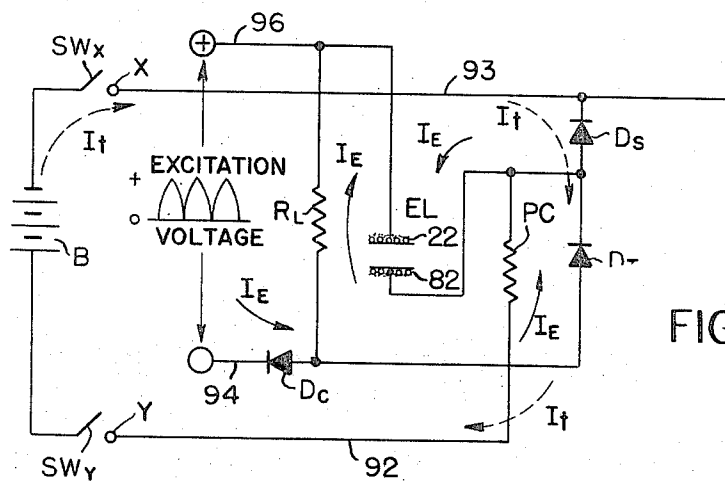


FIG. 10



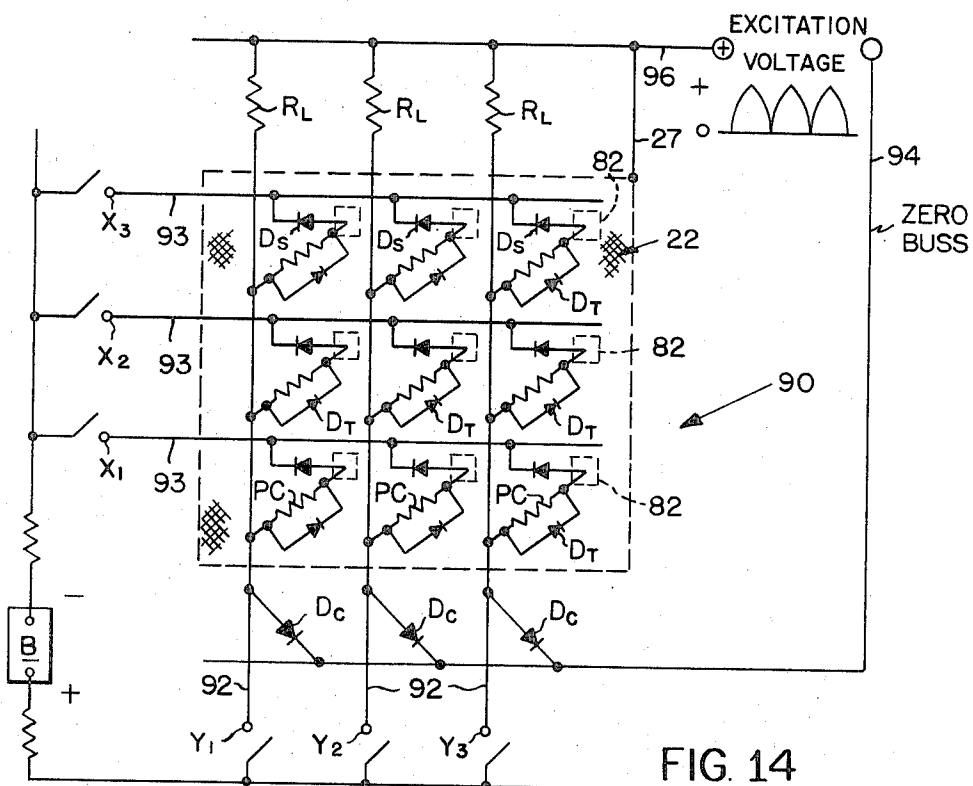


FIG. 14

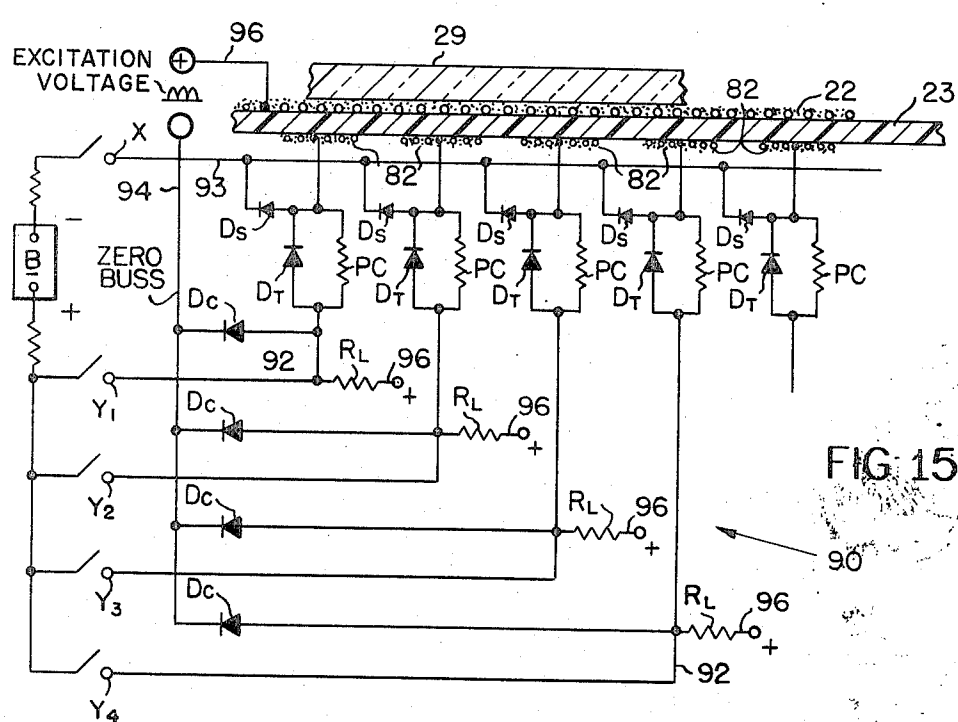


FIG. 15

SOLID STATE ELECTROLUMINESCENT X-Y DISPLAY PANELS

This invention relates to electroluminescent display panels, and more particularly to the "X-Y" or "cross-grid" variety in which electrical inputs are applied co-incidentally to electrodes along selected X and Y axes to produce a spot of light on the panel at the cross point of the energized electrodes.

Cross-grid display panels have been manufactured with the intersecting X and Y strip electrodes on a glass panel in the form of either rectangular or polar coordinates. In such panels one of the X-Y set of electrodes is made of transparent material in order to transmit electroluminescent (EL) light, when proper voltage is applied to the selected pairs of intersecting electrodes. However, a very high ohmic resistance is present along the narrow, transparent, strip electrodes, and due to the fragility of the glass substrate, and to the highly resistive electrodes, the displays are generally limited in size to areas under one square foot. Furthermore, fabrication techniques do not lend themselves to mass production; and hence the unit cost per display is far too high for commercial use. In addition, the useful display life of this known type of X-Y panel is short, because the electroluminescent (EL) phosphors, which are integral parts of this type of panel, diminish in light output as a function of time and excitation conditions, and when the light output falls below acceptable levels, the whole monolithic assembly must be discarded, even though other parts of the panel may still be in satisfactory condition.

It is an object of this invention to provide an improved EL display panel which is capable of being manufactured economically in substantially larger sizes than heretofore practical.

Another object of this invention is to provide a panel of the type described which will have a substantially longer operating life than prior such panels. To this end it is an object also to provide an improved EL panel that has a removable EL face, which can readily be replaced when necessary to prolong the useful life of the panel.

Still another object of this invention is to provide an improved panel of the type described which can be assembled in various sizes by using standard stock materials, such as printed circuit board laminates and pre-tested circuit components.

A further object of the invention is to provide an EL, X-Y coordinate display which is adjustable in degree as to light persistence or "memory".

Still another object of the invention is to provide an EL, X-Y display that can be controlled by low level logic signals.

A further object of this invention is to provide an improved EL panel of the cross-grid variety, which through the use of high quality non-linear components, has a high discrimination ratio between its energized and de-energized light emitting elements or electrodes.

Another object of this invention is to provide an improved EL panel of the cross grid variety, which may be constructed with memory characteristics for maintaining selected cross point electrodes energized for intervals following removal of enabling signals therefrom, thus permitting more rapid operation of the panel.

Another object of the invention is to provide a flat panel display in which the light-emitting surface is a separate part of the device so that it can easily be assembled to, and disassembled from, the parts that make up the total display without detriment to the display, thereby enabling indefinite extension of the life of the display;

Still a further object is to provide an improved EL panel capable of emitting light of various colors and patterns.

Other objects of the invention will be apparent hereinafter from the specification and from the recital of the appended claims, particularly when read in conjunction with the accompanying drawings.

In the drawings:

FIG. 1 is a fragmentary plan view of a rectangular, planar, electroluminescent display panel made in accordance with one embodiment of this invention, portions of the panel being cut away for purposes of illustration;

FIG. 2 is a fragmentary sectional view taken along the line 2-2 in FIG. 1 looking in the direction of the arrows, and with the thickness of certain portions of the panel exaggerated for purposes of illustration;

FIG. 3 is a schematic wiring diagram fragmentarily illustrating one manner in which the panel of FIGS. 1 and 2 may be wired for operation.

FIG. 4 is a fragmentary plan view of a modified form of panel, a polar coordinate display;

FIG. 5 is a fragmentary sectional view taken along the line 5-5 in FIG. 4 looking in the direction of the arrows;

FIG. 6 is a fragmentary plan view of a display panel made in accordance with still another embodiment of this invention, portions of the panel being broken away, and certain of the electrical components thereof being illustrated schematically;

FIG. 7 is a fragmentary sectional view of this panel taken along the line 7-7 in FIG. 6 with portions of its electrical components again being illustrated schematically;

FIG. 8 is a wiring diagram illustrating fragmentarily one manner in which the electrical components of the panel of FIGS. 6 and 7 may be wired for operation;

FIG. 9 illustrates fragmentarily a modification of the wiring diagram shown in FIG. 8;

FIG. 10 is a schematic plan view of still another modification of this panel, portions of its electrical components again being illustrated schematically;

FIG. 11 is a fragmentary plan view of a display panel made in accordance with still another embodiment of this invention, portions thereof being cut away for purposes of illustration;

FIG. 12 is an enlarged, fragmentary sectional view taken along the line 12-12 in FIG. 11 looking in the direction of the arrows, part of the electrical components of the panel being illustrated schematically;

FIG. 13 is a wiring diagram illustrating fragmentarily one manner in which the components of the embodiment shown in FIGS. 11 and 12 may be wired for operation;

FIG. 14 is a fragmentary, schematic plan view of a modification of the display panel of FIG. 11;

FIG. 15 is a diagrammatic view, partly a sectional view of a panel such as shown in FIG. 14; and

FIG. 16 is a wiring diagram showing the circuit for one of the display elements of this panel.

The X-Y panel of this invention is based on a unique method of EL light generation. Light-emitting phosphor is placed on top of a screen electrode, where a fringe field, formed between the screen and a bottom electrode, traverse it. The EL phosphor is excited to luminescence on top of the screen and at its edge openings by the fringing electrostatic flux field. One main advantage of this light-emitting system is that the EL portion can be a separate detachable part of the display assembly by making the bottom electrode part of another assembly.

Each embodiment of the invention comprises three principal elements: an electroluminescent light emitting sheet, a plurality of non-linear electrical components, and a printed circuit board substrate. The light emitting sheet comprises an electrically conductive screen or grid fastened beneath a transparent cover on a layer of dielectric insulating material, and coated with a layer of electroluminescent phosphor, or the like. This sheet is releasably secured on the substrate, with the non-linear electrical components interposed between the sheet and the substrate. The coated grid may be in the form of a plurality of spaced, parallel strips, which extend at right angles over spaced, parallel conductors in the substrate, or radially over concentric, circular conductors in the substrate. The non-linear components are positioned between the sheet and substrate to register with the intersections of the EL electrodes (the phosphor coated grids) and the conductors in the substrate. When an AC voltage is applied between an EL electrode and a conductor in the substrate, the non-linear component located at the intersection of the energized electrodes may be utilized to control the intensity and duration of light that is emitted from the registering portion of the phosphor on the energized EL electrode.

Referring now to the drawings by numerals of reference, and first to the embodiment illustrated in FIGS. 1 to 3, 20 denotes generally an electroluminescent display panel comprising a plurality of spaced, parallel electroluminescent (EL) strips or electrodes 22, which are fastened to the upper surface of a rectangular sheet 23 of transparent dielectric insulating material. Each EL electrode 22 comprises an electrically conductive screen or grid 24, which is coated in known manner with a layer 25 of electroluminescent material, such as phosphor.

At one end (the right end in FIGS. 1 and 2) a marginal portion of each electrode 22 is secured beneath one of a plurality of solid, electrically-conductive metal terminals 27, which are secured to the face of the insulator sheet 23 adjacent its edge. Laminated or otherwise adhered to this assembly to cover the electrodes 22 is a transparent stiffener, or cover panel 29, which may be made from a clear sheet of polycarbonate, such as sold under the trademark "Lexan", or polymethylacrylate.

This assembly, comprising the insulator 23, the EL electrodes 22 and the transparent cover 29, is releasably secured on a printed circuit board or substrate 30 by screw and nut combinations 32. Spacers 33 are interposed between sheet 23 and the substrate 30 to maintain these members in spaced, parallel relation.

Secured on the upper face of the circuit board 30 are a plurality of spaced, parallel metal strips or conductors 35, which extend at right angles to the EL electrodes 22. Removably mounted between electrodes 35 and

the insulator 23 to register with the intersections of the electrodes 22 and 35 are a plurality of pellet-shaped, non-linear electrical components 37. Many materials possess the property of non-linearity when inserted in an electrical circuit. Some of these materials are silicon carbide, selenium, copper oxide, cadmium sulfide, cadmium selenide, barium titanate, strontium titanate, etc. These non-linear materials can be coin pressed and processed into various shapes, such as pellets, discs, rods, spheres etc. At its lower end each component 37 has an electrically-conductive terminal 38, which is seated on one of the electrodes 35; and at its upper end each component has another electrically-conductive terminal 39, which is seated against the underside of the insulator 23.

In the illustrated embodiment, seven EL electrodes 22 are disposed in intersecting relation to five substrate electrodes 35, thereby forming thirty-five intersections (FIG. 1), with each of which a different non-linear component 37 registers. By connecting the EL electrodes 22 through conductors 27 to the terminals X₁ through X₇, and one end of each of the substrate electrodes 35 to the terminals Y₁ through Y₅ (FIGS. 1 and 2), the exact location of each component 37 in the panel 20 may be represented by a specific X and Y coordinate.

As illustrated schematically in FIG. 3, each component 37 may comprise a non-linear resistive element that is operatively connected in series between its associated substrate conductor 35, and the registering, insulated portion 23 of the associated EL electrode 22. The portion of the EL electrode that registers with a respective component 37 depends upon the diameter of the upper electrode 39, which is seated against the dielectric insulator 23.

When a pulsed or alternating voltage (Excitation Voltage in FIG. 3) is applied between any two X and Y terminals (X₁ and Y₁ in FIG. 3), the component 37 located at the intersection of the two associated electrodes 22 and 35 will conduct sufficiently to cause a changing electric field to be generated between its upper terminal 39 and the energized screen electrode 22. Electric field fringe lines will traverse the EL phosphor particles and excite them to luminescence, and the portion of the EL electrode that registers with the terminal 39 on the conducting component 37 located at the intersection of the two energized electrodes will be caused to glow, or emit light. The remaining components 37, which are not located at the intersection of two energized electrodes, will operate to suppress the application of voltage to their terminals 39 at this time, thereby preventing any cross effect or undesirable illumination of any portions of the electroluminescent material adjacent to the intersection of the energized electrodes.

It will be apparent that one or more spots on the panel 20, which register with components 37, may be caused to glow selectively merely by selective application of an AC or intermittent voltage to selected pairs of X and Y terminals of the panel. These spots will remain illuminated, however, only so long as the excitation voltage is applied to their associated X and Y coordinates.

It should be noted that the EL sheet may be replaced at will, and so may any non-linear resistor element. Further, the display can be driven from a computer or integrated circuit logic via a buffer stage which switches

the voltage levels needed to light the EL display elements.

In the modified display panel shown in FIGS. 4 and 5, wherein like numerals are employed to denote elements similar to those employed in the first embodiment, the EL electrodes 22 are positioned between the insulator 23 and transparent cover 29 in equi-angularly spaced relation about a screw and nut combination 32 that is employed to secure the light emitting assembly to a printed circuit substrate 42. On its upper face, substrate 42 has three, circular, concentric, radially spaced electrodes 43, which are disposed coaxially of the center screw 32. Each radial EL electrode 22 is disposed in registering, intersecting relation to the two outermost substrate electrodes 43, while only the alternate EL electrodes 22 are disposed in intersecting relation to all three of the substrate electrodes 43.

As in the first embodiment, non-linear electrodes 37 are positioned between the insulator 23 and substrate 42 to register with the intersections of the substrate electrodes 43 and the radial electrodes 22. The outer ends of the radial electrodes 22 are connected to different terminals, respectively, denoted in FIG. 4 as terminals X_1 , X_2 , etc.; while the circular substrate electrodes 43 are connected to three electrodes Y_1 , Y_2 and Y_3 , respectively.

Panel 40 thus provides a polar coordinate array, wherein by application of an AC or pulsating voltage across any two preselected X and Y terminals, a spot of light may be produced on the face of the panel at any one of a plurality of different angularly and radially spaced points about the axis of the central mounting screw 32. In this embodiment, as in the first embodiment, a given spot on the panel 40 will be caused to glow only so long as the AC or pulsating voltage is applied across its associated X and Y terminals.

If a control element, such as an SCR or a transistor is inserted in the circuit, the EL light elements may be switched on and off electronically. When a number of these circuit elements are arranged in an X-Y array, or in a polar coordinate array, a multi-function, flat-screen display can be achieved by switching selected EL light elements on and off in accordance with a programmed signal. Such an arrangement is shown in FIGS. 6 to 8, wherein like numerals are again employed to denote elements similar to those incorporated in the preceding embodiments, and where 50 denotes a modified light panel having short term memory capabilities which enable the intensity and duration of illumination of selected spots on the panel to be controlled. As in the embodiment of FIGS. 1 to 3, the light emitting assembly comprises a plurality of spaced, parallel electrodes 22 that are sandwiched between the insulator sheet 23 and a transparent cover 29. This assembly is secured by screws 32 and spacers (not illustrated) to a printed circuit substrate 52. Secured on the upper face of substrate 52 is a ground bus electrode 53 having a base portion that extends along one side of the substrate, and a plurality of spaced, laterally projecting, parallel leg portions 53-1, 53-2, 53-3, etc., which extend beneath and at right angles to the EL electrodes 22. A further plurality of electrodes 54 are secured on the underside of substrate 52 in parallel relation to the ground bus projections 53-1, 53-2, 53-3, etc.

Arrayed in spaced rows and columns between insulator 23 and the substrate 52 are a plurality of non-linear components 57, each of which contains a silicon con-

trolled rectifier (SCR) of the type shown schematically in FIGS. 7 and 8. At its lower end, each component 57 has the cathode of its SCR connected to an electrically conductive plate 58, which is seated on one of the ground bus projections 53-1, etc., overlapping one of the substrate conductors 54. Each component 57 has the anode of its SCR connected to an electrically conductive plate 59 that is seated against the underside of the insulator 23. As shown schematically in FIG. 7, the triggering or gating terminal of each SCR is electrically connected with the adjacent substrate electrode 54 by a probe 56, which projects through registering openings in the substrate 52 and the cathode end 58 of each component 57. This construction enables each component 57 to be removed and replaced, if necessary.

Along one side of the circuit board 52 (lower side in FIG. 6) each electrode 54 is connected through a resistor R_1 to one of a plurality of column-selecting terminals Y_1 , Y_2 , Y_3 , etc. (FIGS. 6 and 8). Each of these terminals is also connected to the ground bus 53 through a condenser C_1 , which functions with the associated resistor R_1 to form a time delay circuit between the respective column-selecting terminal Y_1 , Y_2 , etc. and the ground bus 53.

Each of the terminals 27 of the EL electrodes 22 of panel 50, only four of which are illustrated in FIG. 6, is connected by a line 61 to the collector of one of four PNP transistors denoted schematically at Q_1 , Q_2 , Q_3 and Q_4 , respectively. The emitters of these transistors are connected by a line 62 to the ground bus 53. Each collector lead 61 is also connected through a separate load resistor R_3 and a line 64 to one side of an AC or pulsating excitation voltage, the opposite side of which is connected through the line 62 to the ground bus 53. The base of each transistor Q_1 , Q_2 , Q_3 and Q_4 is connected through a resistor R_2 and a line 65 to one of four row-selecting terminals located adjacent one end of the circuit board 52 and denoted in FIG. 6 at X_1 , X_2 , X_3 and X_4 , respectively. Each row-selecting terminal X_1 , X_2 , etc., is also connected to ground through a condenser C_2 , which is connected between the associated terminal lead 65 and the bus 53.

In operation, one side of an AC or pulsating excitation voltage is applied through the line 64 and load resistors R_3 to each of the EL electrodes 22, and to the collector terminals of the transistors Q_1 through Q_4 ; and the opposite side of this voltage is applied by line 62 to the ground bus 53, and through each of the time delay circuits R_2 - C_2 to the base of each transistor. Unlike the preceding embodiments, the excitation voltage is connected at all times across all of the EL electrodes 22 of panel 50, so that whenever a positive DC triggering signal is applied to any one of the column-selecting terminals Y, for example terminal Y_1 , this signal is applied through a resistor R_1 simultaneously to all of the gating terminals 56 of the SCR components 57 in this column, so that the latter are gated or caused to conduct, thereby placing their associated anode terminals 59 at approximately ground potential. This tends normally to cause portions of each of the registering EL electrodes 22 to glow, thereby to form a column of glowing spots on the face of the panel 50. However, at this time the transistors Q_1 , Q_2 etc. are also conducting, thereby effectively shunting out all of the SCR components 57 so that virtually all of the excitation voltage appears across the load resistors R_3 . As a result, only a small fraction of the excitation voltage appears across

the EL electrodes 22, and this voltage is not sufficient to cause the portions of the EL electrodes 22, that register with the now-conducting SCR components 57 — i.e., the components controlled by terminal Y_1 in the example under consideration, to glow.

If at this time a sufficient positive DC signal is applied also to one of the X or row-selecting terminals, then the associated transistor Q_1, Q_2 , etc. is switched to a blocking or substantially non-conductive state. This will increase the AC voltage drop across the intersecting X and Y coordinates sufficiently to cause the registering portion of the EL electrode to glow. For example, assuming that positive DC signals are applied simultaneously to the terminals X_1 and Y_1 of panel 50, the transistor Q_1 is switched to a blocking or non-conductive mode so that current ceases to flow in its collector-emitter circuit. Since the SCR component 57 illustrated in the lower right hand corner of FIG. 8 (in column Y_1) is now conducting, substantially all of the excitation voltage applied to this component is dropped across the component and the registering portion of the associated EL electrode 22, so that the electroluminescent phosphor on this portion only of this EL electrode is made to glow, while the remaining EL sectors registering with the column Y_1 do not glow because their associated transistors Q_2, Q_3 , etc. are still conducting and shunting the excitation voltage which otherwise would be applied across their associated SCR components 57.

From the foregoing it will be apparent that, by selectively applying positive triggering signals to selected X and Y terminals in the panel 50, selected portions of the grid represented by the spaced electrodes 57 may be caused to glow in a manner generally similar to that in the previously described embodiments. However, panel 50 has the additional advantage that triggering signals applied to its X and Y terminals can be made to persist for periods of time after the voltages have been removed from the terminals. For example, when a positive DC signal is applied to terminal Y_1 , the condenser C_1 immediately charges, so that upon subsequent removal of the signal, the condenser discharges through the associated resistor R_1 , and thus maintains the triggering terminal of each SCR 57 in the associated column at a positive potential for the period of time that it takes for the condenser to discharge. Similarly, when a positive DC signal is applied to one of the X terminals, the associated condenser C_2 immediately charges, and upon subsequent removal of the signal this condenser maintains the base of the associated transistor Q_1 positive until the condenser C_2 discharges through the associated resistor R_2 .

This short term memory feature allows panel 50 to be employed in conjunction with conventional scanning apparatus which may operate, for example, to keep all of the EL sectors associated with row X_1 enabled or energized for a predetermined period after a triggering signal has been removed from terminal X_1 . During this interval the column terminals Y_1, Y_2 , etc. may be scanned or triggered successively. Under these circumstances, of course, the time delay period provided by the column delay circuits C_1, R_1 would have to be shorter than that afforded by a respective row selecting delay circuit R_2, C_2 .

Moreover, since the ratio of the light intensity developed at each spot on the panel 50 is a function of the current flowing through the associated blocking tran-

sistor Q_1, Q_2, Q_3 , etc; the circuitry of panel 50 enables the intensity of the light emitted at each spot on the panel to be controlled merely by modulating the control voltage applied to the row-selecting terminals X_1, X_2 , etc. For example, instead of applying to the terminal X_1 a DC voltage large enough completely to shut off transistor Q_1 , the triggering voltage at X_1 may be selected merely to reduce the current flow in the collector-emitter circuit of this transistor, thus to shunt part only of the excitation voltage across the associated load resistor R_3 , and to allow the remainder of this voltage to be applied across the selected SCR component 57. This causes the registering portion of the associated EL electrode 22 to glow with an intensity less than that which would occur if this transistor Q_1 were to be switched completely to a non-conductive mode.

If control of light intensity for the panel 50 is not desired, its circuit may be modified, as illustrated fragmentarily in FIG. 9, by substituting an SCR element 68 for each of the transistors Q_1, Q_2, Q_3 , etc. Each such element 68 has its anode connected through one of the lines 61 (FIGS. 8 and 9) to the associated load resistor R_3 , and its cathode connected directly through line 62 to the ground bus 53. The gating terminal 69 of each element 68 is connected through a resistor R_2 and condenser C_2 to ground, and through the same resistor R_2 to one of the row-selecting terminals X_1, X_2 , etc. Thus, whenever a positive DC signal is applied to one of these terminals, the associated element 68 is rendered conductive to shunt the excitation voltage through the SCR 68 to ground, thereby preventing illumination of any portion of the EL electrode 22 that is connected by line 61 to the anode of this element. In this embodiment, then, in order selectively to illuminate a particular spot on the panel 50, assuming one of its column-selecting terminals Y is energized, it is necessary also to apply gating or shunting signals to all but one of the row-selecting terminals X.

FIG. 10 illustrates schematically still a further modification of the invention. FIG. 10 shows an array of red, blue and green EL elements which make up a three-color X-Y display. The physical arrangement and electrical connections are very similar to those shown in FIGS. 6, 7 and 8. The difference is that all red elements are in discreet rows and columns as well as are the blue and green elements. If it is desired to display a green image alone, signal voltages are applied only to row and column gates containing the green EL light-emitting elements. So it is similarly where a totally blue or a totally red display is desired; the control signals are applied to the appropriate control gates in the blue rows and columns or in the red rows and columns. Three separate display colors may also be presented simultaneously but independently, one screen in red, one in blue, one in green by feeding the color signals to corresponding row and column gates in sequence.

In the embodiment of FIG. 10 the horizontally disposed EL electrodes 22 are positioned closer to one another; and adjacent electrodes 22 are tinted differently to produce differently colored light, when energized. For example, starting with the lowermost electrode 22, the phosphor layer on the first is tinted blue, the second red, and the third green. This pattern is repeated, the fourth row from the bottom being tinted blue, the fifth red, and the sixth green, etc. Positioned closely adjacent each other beneath each electrode 22 with their anode plates 59 (broken line rectangles in FIG. 10)

seated against the insulator 23 (not illustrated) are a plurality of SCR components 57 of the type employed in panel 50. Also as in panel 50 an AC or pulsating excitation voltage is connected at one side by load resistors R3 and line 61 to the EL electrodes 22, and through the collector-emitter circuit of a transistor Q to ground 62, the base of each of these transistors being connected through a time delay circuit R_2-C_2 to ground.

Since in the embodiment of FIG. 10 there are three differently colored electroluminescent electrodes, the bases of the transistors Q that control the blue electrodes 22 are connected to the row-selecting terminals X_{B1} , X_{B2} , X_{B3} ; the bases of the transistors controlling the red electrodes 22 are connected through the row-selecting terminals denoted X_{R1} , X_{R2} , X_{R3} ; and the bases of the transistors controlling the green electrodes 22 are connected to the row-selecting terminals X_{G1} , X_{G2} , etc. The SCR elements 57 of adjacent EL electrodes 22 are offset horizontally from each other, so that those beneath every third row of electrodes 22 register vertically to form columns of vertically spaced components 57. The anodes of all components 57 in each column thereof are connected to one of a plurality of column-selecting terminals denoted as Y_{G1} , Y_{R1} , Y_{B1} , Y_{G2} etc. In FIG. 10 each column of components 57 is illustrated schematically by the representation of a single SCR element; but it will be understood that there is one such SCR element for each illuminable spot of light on this cross-grid type panel. Also, although only one time delay circuit $C_1 - R_1$ is illustrated in this figure between the Y_{R5} column-selecting terminal and ground, it will be understood that one such time delay circuit is interposed between each column-selecting terminal and ground.

When a positive gating signal is applied to any one of the Y terminals of the panel of FIG. 10, for example to terminal Y_{G1} , the SCR's that register with the right ends of the green electrodes 22 will conduct, so that if a positive blocking signal is applied at the same time to one of the row-selecting terminals X_{G1} , X_{G2} , etc., a green spot will be caused to glow at the right end of the green electrode 22 which registers with the selective, or energized, X and Y coordinates. Selected red or blue spots on the panel may be caused to glow in a similar manner by proper selection of the associated X and Y coordinates; or a plurality of differently colored spots, or spots all of the same color, may be caused to glow on the panel by the application of positive DC signals to selected pairs of the X and Y coordinates of this panel. Thus, either a solid color or a multi-colored display can be produced; and by incorporating electroluminescent electrodes 22 having still differently tinted electroluminescent material, additional colors may be incorporated in the panel, provided that their associated non-linear components 57 are properly arranged in separate or offset columns as described above in connection with the red, blue and green colors.

In any such multi-color display, of course, it is necessary that each EL element and its associated control component 57 be made relatively small, so that sufficient resolution can be achieved. In the embodiment illustrated in FIG. 10, a multi-color display can be achieved by addressing a group of red, green and blue EL elements 22 in much the same manner as is done in color TV tubes, where the red, green and blue dots are mixed to produce the colored images. Moreover, as in

the embodiment illustrated in FIGS. 6 to 8, the time delay circuits (R_2-C_2) interposed between the X coordinates and the bases of the associated transistors Q may be utilized to cause the signals supplied to successive groups of three of the X coordinates, for example, to persist or remain "on" for a time duration equal to the time it takes to scan three of the Y coordinates. Moreover the intensity of each of the color EL elements 22 may be controlled by the amplitude of the DC signal applied through the corresponding X terminal to the base of its associated transistor Q, as described in connection with the embodiment of FIGS. 6 to 8.

FIGS. 11 to 13 illustrate a modified panel 70 which has latching memory capabilities, in the sense that once a spot on the panel has been illuminated it will remain illuminated indefinitely after the removal of the triggering signals from its associated X and Y coordinates. This embodiment employs a single, large electroluminescent screen electrode 22, which is common to all electronic elements in the components section. The screen is sandwiched between a layer of insulation 23 and a transparent cover 29 to form a light emitting assembly that is removably secured on a printed circuit substrate 72 in a manner similar to that of the preceding embodiments. This light emitting assembly, however, includes a plurality of small, rectangular, opaque light shields 26, which are secured in intersecting rows and columns beneath the cover 29, and over the single electro-luminescent electrode 22. Interposed between the insulator 23 and substrate 72 are a plurality of rectangular, non-linear electrical components 77, which also are arranged in intersecting rows and columns so that each light shield 26 registers vertically with part of one of the electrodes 77.

On its upper face substrate 72 has a plurality of spaced, parallel conductors 73, which are connected adjacent one end of panel 70 to row-selecting terminals X_1 , X_2 , X_3 . A ground bus or electrode 74 on the underside of substrate 72 has a base portion that extends along one edge of the substrate, and a plurality of spaced, parallel leg portions 74-1, 74-2, 74-3, etc., each of which extends beneath a column of the components 77 in right angular, intersecting registry with the conductors 73. On its underside substrate 72 also has a plurality of spaced, parallel conductors 75, which extend beneath components 77 parallel to the legs of bus 74, and which are connected adjacent one side of panel 70 to the column-selecting terminals Y_1 , Y_2 , Y_3 , etc.

As shown in FIG. 12, each component 77 has in its upper end two chambers or recesses 78 and 79. Secured to the upper end of each component 77 over its chamber 78 is a rectangular, electrically conductive plate or back electrode 81. Secured in a rectangular notch in one side of each plate 81 to register vertically with part of the chamber 79 in the associated component 77, and with the light shield 26 that is positioned above this component, is a small rectangularly shaped EL electrode 82 similar in construction to the electrode 22.

Encapsulated in the chamber 78 of each component 77 is an SCR element (FIG. 12), which has its cathode connected directly to the associated back electrode 81, and its anode connected through a photoconductive cell PC to the same back electrode 81. The anode of each such SCR is also removably connected, for example by a conventional probe 83 (FIG. 12) that extends through a registering opening in the substrate 72, to

one of the ground bus legs **74-1**, **74-2**, etc. Its cathode is also connected in series with a diode **Ds** and another probe **85** to a row-selecting conductor **73**. The gating or triggering terminal of each of these SCR's is connected, for example by a conventional probe **84**, with one of the column-selecting conductors **75**.

The back electrodes **81** of the EL sheet are isolated areas which define the shape of the EL light. Each of the back electrodes is a solid conducting area except for the small screen opening. This opening is necessary for the EL light from a cell to shine through the screen onto the photosensitive face of the associated photoconductive component.

The single, upper EL electrode **22** is connected at one end by a terminal **27** and line **86** to one side of an AC or pulsating excitation voltage, which is connected at its opposite side to the ground bus **74**, so that the excitation voltage may be applied at all times to electrode **22**. The excitation current is designed to follow a series path through the EL cell, and through a parallel connected photoconductive cell with SCR and thence back to the excitation source at ground potential. Note that the entire array of light-emitting elements are connected in parallel across the excitation voltage source.

Normally, when the SCR's of the components **77** are not conducting, this excitation voltage is divided between the capacitive reactance of electrode **22**, and the parallel impedance presented by each non-conducting SCR and its associated photoconductor PC. The photoconductors and SCR's are selected so that, when no triggering voltages are applied to the associated X and Y terminals, the capacitive reactance of electrode **22** is less than the parallel impedance of the photoconductor PC and the SCR of each component **77**, so that substantially all of the exciting voltage is dropped across the PC-SCR combinations. Therefore, at this time not enough of the exciting voltage is dropped across the EL cell to cause it to glow.

When a positive DC gating signal is applied to one or more of the column-selecting terminals Y, and a negative DC triggering voltage is applied to a like number of the row-selecting terminals X to bias the associated series diodes **Ds** forwardly, then the SCR's located at the intersections of these energized X and Y terminals will be gated and will conduct. This has the effect of causing the associated back electrode **81** of each conducting SCR to be brought substantially to ground potential, so that the portions of the upper EL electrode **22** that register with these electrodes **81**, and also the adjacent lower EL electrodes **82**, are caused to glow. Whenever one of the lower EL electrodes **82** is energized and caused to glow, light therefrom is directed onto the PC element in the recess **79** of its associated component **77**, causing the photoconducting to increase to a point where resistance of this PC element falls to a very low value, thereby producing a shunt circuit across the associated SCR from ground to its back electrode **81**. Consequently, when the triggering voltages are removed from the X and Y terminals of an SCR to switch it back to its blocking or non-conductive state, the associated back electrode **81** will remain substantially at ground potential because of the hunting effect of the adjacent PC element, so that the associated portions of the upper and lower EL electrodes **22** and **82** continue to glow as long as the excitation voltage is maintained between the upper electrode **22**, and the

ground bus **74**. This is so because of the low resistance state of the photoconductive unit which now is the controlling element. The SCR unit is the first member of the electronic module to turn "on" the EL cell. After the triggering voltage has been removed, the EL radiation from an energized electrode **82** activates the adjacent photoconductor PC to a low resistance state; and the associated SCR then reverts back to its "off" state of high resistance. The diodes **Ds** at this time prevent any unselected EL cell from receiving excitation voltage from adjacent lit, or energized cells, on the same row selecting line **73**.

In panel **70** opaque masks **26** are employed to prevent any ambient or external light from entering the recesses **79** in the components **77**, thus assuring that the resistance of each PC element will be controlled solely by radiation from the adjacent EL element **82**. In this embodiment, therefore, whenever one or more X-Y coordinates or terminals are energized with the necessary positive and negative potentials, the selected portions of the upper electrode **22**, and the associated lower EL electrodes **82**, will remain "on" or lighted for as long as the excitation source voltage is maintained.

In order to "erase" the display, the excitation voltage must be removed. Lack of radiation impinging on the photoconductor will cause it to change from a low resistance state back to its normal high resistance state. The speed of the response of the display **70** will depend on the type of the photosensitive element employed. Some of the materials used for making such elements are: silicon, germanium, lead sulphide, selenium, cadmium sulphide, cadmium selenide, etc. These materials may be in the form of photo-resistors or phototransistors.

The latching display panel **90** of FIGS. **14** to **16** differs from the latching memory display **70** in FIGS. **11** to **13** in that only diodes **Ds** and **Dt** and photoconductors PC are employed as non-linear elements. As in panel **70**, a single upper screen electrode **22** is common to all non-linear elements, while the lower (back) screen electrodes **82** are isolated, discreet areas positioned to direct light onto adjacent photoconductors PC, when illuminated. The dielectric film **23**, which contains the upper and lower screen electrodes **22** and **82** is opaque, so as to prevent the ambient light on the upper or observer's side of panel **90** from triggering the photoconductors PC into their low-resistance states.

For panel **90** the excitation voltage comprises a unidirectional, pulsating positive voltage having a wave form generally similar to that shown in FIGS. **14** to **16**. This voltage supply maintains bus **94** at zero potential, and applies the positive signal through line **96** and separate load resistors **R_L** and lines **92** to each of the Y or column selecting terminals **Y₁**, **Y₂**, **Y₃**, etc. Each Y terminal is also connected through a separate coupling diode **D_C** to the zero potential bus **94**; through series connected diodes **D_T** and **D_S** to one of the row selecting conductors **93** that are connected, respectively, to the row selecting terminals **X₁**, **X₂**, **X₃**, etc.; and through a photoconductor PC with one of the back electrodes **82**, each such photoconductor PC being connected in parallel with its associated triggering diode **D_T**. As in the case of the preceding embodiments, the non-linear elements **D_S**, **D_T** and PC for each back electrode **82** may be enclosed in a dielectric housing that is removably mounted as a replaceable component between the insulation layer **23** and a printed circuit board containing

the zero bus 94 and X and Y selecting electrodes 93 and 92, in a manner that will be readily apparent to one skilled in the art from the above disclosure.

Referring to the equivalent circuit in FIG. 16, when the excitation source voltage is applied between lines 94 and 96, a unidirectional, pulsating positive voltage appears across the upper EL cell 22, and each back EL cell 82 and its associated non-linear elements. When these EL cells (FIG. 16) are illuminated, the excitation current flow I_E (electron flow) is in a direction through the coupling diode D_C , through the parallel connected photoconductor PC and trigger diode D_T , through the EL cells and thence to line 96 and the positive excitation terminal. High value load resistor R_L shunts the EL cells and provides a discharge path through the low impedance of the photoconductor PC between pulses.

The trigger current I_t , shown in FIG. 16 by the dotted arrows, flows from a battery or direct current power supply B through switch SW_X , through the series blocking diode D_S , through the trigger diode D_T and thence through the Y-axis switch SW_Y and back to the trigger voltage source B, thus completing the circuit.

When excitation voltage is applied across the display terminals, (and in the absence of triggering voltage), most of the pulsating excitation voltage appears across the high impedance of the "back biased" junction of the triggering diode D_T which is in parallel with the high dark resistance of the photoconductor PC. In other words, the a.c. impedance of the EL cells is lower than the impedance of the parallel PC- D_T combination, and due to the relation, $E = IZ$, most of the excitation voltage will be developed across the higher of the two impedances in series. Thus the EL cells will not light because of insufficient voltage across them.

If now an X-Y coordinate trigger voltage is applied from source B, triggering current I_t will flow through triggering diode D_T in the forward direction, causing the impedance of the diode to instantaneously drop to a very low value. At this instant of time, the greater part of the excitation voltage is shifted across the EL cells, whose a.c. impedance is now higher than that of the PC- D_T parallel combination. The EL cells therefore emit light at the chosen X-Y point.

EL light generated at the upper screen shines toward the observer while EL light from the back screen sector 82 shines on the photoconductor PC, whose high impedance instantly falls to a very low value.

When the triggering voltage is removed, the diode D_T reverts back to its high resistance state, but the EL cell will remain lit because of its optical coupling to the photoconductor PC, keeping it in its low-resistance state. The EL cell will remain lit as long as the excitation voltage is maintained across the display.

The function of the series diode D_S is to prevent any unselected EL cell from receiving excitation voltage from adjacent lit cells on the same X-axis feed line. If the diodes D_S were not there, all cells in the selected X-axis row would light up. In order to "erase" the display on panel 90, the excitation voltage must be interrupted for a time long enough for the photoconductors to change back to their high "dark" resistance. Dark resistance is defined as the internal impedance of the photoconductor in the absence of radiation impinging upon it.

From the foregoing it will be apparent that the instant invention provides a novel EL electroluminescent display

panel that is substantially sturdier and more versatile than prior such panels.

While the invention has been described in connection with several different embodiments thereof and various uses therefor, it will be understood that it is capable of further modification and use, and this application is intended to cover any embodiment or use of the invention that comes within the invention and the disclosure or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. An electroluminescent display panel, comprising a pair of electrodes, one of which is coated on one side with electroluminescent material, a layer of dielectric material disposed at the opposite side of said one electrode, means for releasably securing said electrodes together with said layer of dielectric material positioned between and separating said electrodes, and with the coated side of said one electrode facing outwardly, means for applying a pulsating voltage across said electrodes to excite said electroluminescent material, a non-linear electrical element removably positioned between said layer of dielectric material and the other of said two electrodes with one end of said non-linear element releasably engaging said dielectric material and with its opposite end releasably and electrically connected to said other electrode,

said element having an impedance operative normally to prevent significant current flow between said ends thereof and thereby to prevent the portion of electroluminescent material registering with said element from glowing, and control means operable during application of said pulsating exciting voltage selectively to reduce said impedance sufficiently to cause said registering portion of the electro-luminescent material to glow.

2. An electroluminescent display panel as defined in claim 1, wherein said control means is operative for increasing and decreasing, selectively, the impedance of said non-linear element during application of said exciting voltage thereby to vary the intensity with which said registering portion of said electroluminescent material glows.

3. An electroluminescent display panel as defined in claim 1, wherein

said element comprises a solid state switching device normally disposed in a non-conductive mode to present a high impedance to current flow between opposite ends of said element, and

said impedance control means comprises means for selectively switching said device to its conductive mode, when said exciting voltage is applied across said electrodes

4. An electroluminescent display panel as defined in claim 3, wherein said impedance control means comprises

means for applying a pair of voltage signals to said device,

means responsive to said signals to switch said device from its non-conductive to its conductive mode, and

means for causing said registering portion of said electroluminescent material to glow with an intensity and duration proportionate to the intensity and duration of one of said signals.

5. An electroluminescent display panel as defined in claim 4, including means operative, once said device has been switched to its conductive mode, to maintain said device in the last-named mode while said exciting voltage is applied across said electrodes.

6. An electroluminescent display panel, comprising a first electrode having on one side a layer of dielectric insulation, and on its opposite side a layer of electroluminescent material,

a substrate having thereon a second electrode, means for releasably securing said first electrode to said substrate with said insulation disposed in spaced, confronting relation to said substrate, a plurality of spaced, electrically conductive back electrodes disposed between said insulation and said substrate, and seated against the underside of said insulation to register with spaced portions of said electroluminescent material on said first electrode,

a plurality of non-linear and normally non-conducting electrical elements connecting said back electrodes to said second electrode,

means for applying a pulsating voltage across said first and second electrodes, and

means for selectively switching said elements to conducting modes selectively to apply the potential on said second electrode to selected ones of said back electrodes thereby to cause only the portions of said electro-luminescent material in registry with said selected back electrodes to excite and glow, when said pulsating voltage is applied across said first and second electrodes.

7. An electroluminescent display panel as defined in claim 6, wherein

the last-named means includes means for simultaneously switching a plurality of said elements to their conductive modes thereby to cause registering portions of said electroluminescent material to be excited by said pulsating voltage, and certain of said registering portions of said material are tinted differently in color from other portions thereby to cause said display panel to glow in different colors, when excited.

8. An electroluminescent display panel as defined in claim 6, including

a section of electrically conductive wire mesh connected to each of said elements and coated with a layer of electro-luminescent material and illuminable by said pulsating voltage when the non-linear element associated therewith is in its conducting mode, and

a photoconductive member confronting each of said mesh sections and responsive to the illumination of the electroluminescent material thereon to maintain the associated element in its conductive mode until said pulsating voltage is removed from said first and second electrodes.

9. An electroluminescent display panel as defined in claim 8, wherein

a diode is connected in parallel with each of said photoconductive members between said second electrode and one of said wire mesh sections normally to prevent illumination of the said electrolumi-

nescent material on the last-named section, and said registering portion of the first-named electroluminescent material, and

said switching means includes means for selectively applying a forward bias to said diodes to switch the latter from non-conducting to conducting modes thereby to effect selective illumination of the associated electroluminescent material.

10. An electroluminescent display panel as defined in claim 6, wherein

said back electrodes are arranged in parallel rows and intersecting columns beneath said insulation, and

said elements comprise a plurality of solid state switches normally disposed in non-conducting modes to impede current flow between said back electrodes and said second electrode, but operative, when conducting, to cause the voltage on said second electrode to be applied to the associated back electrode.

11. An electroluminescent display panel as defined in claim 10, wherein said switching means comprises

a first plurality of terminals corresponding in number to the number of rows of said back electrodes and arranged at spaced points along a first axis,

a second plurality of terminals corresponding in number to the number of columns of said back electrodes and arranged at spaced points along a second axis transverse to said first axis, and

means connecting each of said switches to at least one of said terminals to be switched thereby to a conducting mode, when a predetermined signal appears at said one terminal.

12. An electroluminescent display panel as defined in claim 11, wherein each of said switches is connected to one each of said first and second terminals to be switched selectively to a conducting mode upon the appearance of predetermined signals simultaneously at the two terminals to which the switch is connected.

13. An electroluminescent display panel as defined in claim 11, wherein

a plurality of said first electrodes are secured on said substrate in parallel rows to register with said rows of said back electrodes,

said means for applying said pulsating voltage across said first and second electrodes comprises an AC voltage source and a further plurality of solid state switches interposed between said first electrodes and said AC voltage source and normally disposed in a first mode to block AC current flow between said first and second electrodes, and

means connecting each of said further switches to another of said terminals to be switched thereby to a second mode to allow AC current flow between the last-named electrodes, when a predetermined signal appears at said other terminal.

14. An electroluminescent display panel as defined in claim 13, wherein

each of the first-named solid state switches comprises an SCR element connected between one of said back electrodes and said second electrode with its gating terminal connected to one of said second plurality of terminals, and

each of said further plurality of switches is connected to one of said first plurality of terminals to be controlled thereby.

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15. An electroluminescent display panel as defined in claim 13, wherein

each row of said first electrodes has the electroluminescent material thereon tinted a color different from that of the two adjacent rows thereof, and

said columns of said back electrodes are arranged so the back electrodes in each column register with rows of said first electrodes having electroluminescent material of the same color, and so that the back electrodes of adjacent columns register with

different rows of said first electrodes.
16. An electroluminescent display panel as defined in claim 12, including light sensitive means operative, when one of said switches is switched to its conducting mode, to maintain the last-named switch in its conducting mode after the disappearance of said predetermined signals from said one each of said first and second terminals, as long as said pulsating voltage is applied across said first and second electrodes.

17. An electroluminescent display panel as defined in claim 16, wherein said light-sensitive means comprises

a further plurality of spaced electrodes secured to the underside of said insulation adjacent said back electrodes and coated with electroluminescent material which is caused to glow whenever the adjacent back electrode is energized by the switching of one of said switches to its conducting mode, and

a photoconductor interposed between each of said back electrodes and said second electrode and responsive to the light emitted by the electroluminescent on the adjacent one of said further electrodes to conduct and apply the voltage on said second electrode to the associated back electrode.

18. An electroluminescent display panel comprising

a first plurality of spaced electrodes coated with electroluminescent material,
a layer of dielectric material on which said electrodes are mounted,

a substrate disposed below said layer of dielectric material and having a second plurality of spaced electrodes mounted thereon and angularly disposed transverse to the first-named electrodes, so that portions of the second-named electrodes register vertically with portions of said first-named electrodes,

a plurality of non-linear, electrically-conductive elements releasably disposed between said substrate and said dielectric material at the points of registry of the first-named and second-named electrodes, and each being in contact at one end with said dielectric material and at its opposite end with one of said second-named electrodes, and

means for selectively applying to one each of said first and said second pluralities of electrodes, respectively, and across the associated conductive element disposed between the registering portions

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of the selected electrodes, a pulsating voltage operative to cause the electroluminescent material on the registering portion of the selected first-named electrode to excite and glow.

19. An electroluminescent display panel as claimed in claim 18, wherein said first plurality of electrodes extend at right angles to said second plurality of electrodes.

20. An electroluminescent display panel as claimed in claim 18, wherein the electrodes of one of said two pluralities of electrodes are circular and concentric of one another and the electrodes of the other of said pluralities of electrodes are arranged radially of the center of said circular electrodes.

21. An electroluminescent display panel as claimed in claim 18, wherein

each of said electrically conductive elements includes a solid state switching device normally disposed in a non-conducting state to prevent excitation of said electroluminescent material on said registering portion of the selected first-named electrode, and

said voltage applying means including means for selectively switching a plurality of said devices to their conducting states to enable excitation of said electroluminescent portions thereof by said pulsating voltage.

22. An electroluminescent display panel comprising

a transparent cover,

an electrically conductive grid, comprising a first plurality of spaced electrodes, mounted on one side of said cover and coated on one side with an electroluminescent material facing said cover;

a dielectric sheet disposed on the side of said grid remote from said cover,

a substrate, having a second plurality of electrodes mounted thereon in spaced relation,

means releasably securing said cover, grid and sheet on said substrate with said sheet disposed in spaced relation to said substrate, and with said second electrodes disposed in angular relation to said first electrodes,

a plurality of spaced, non-linear and normally non-conducting electrical elements removably mounted in the space between said sheet and said substrate, and contacting at opposite ends with said sheet and the last-named electrodes, respectively,

said elements being disposed between registering portions of said first and second pluralities of electrodes, and

means for simultaneously applying a pulsating voltage to selected electrodes in each of said first and second pluralities selectively to switch the elements between the registering portions of the selected electrodes to their conducting modes thereby to cause the portions of the electroluminescent material registering with said conducting elements to excite and glow.

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