An illuminated display provided by exciting a phosphor surface to luminescence and heating selected areas of the phosphor surface to quench luminescence theretofor to produce a desired display pattern. One display panel version has a plurality of separate and spaced thin film resistors bonded on a support surface provided by an insulative substratum, with the resistors and support surface covered by an overlay of phosphor. The overlay is an even uniform dispersal of particles of several different photoluminescent compounds, each producing a different color upon excitation and having a different quenching temperature range. Thin film conductors connect the resistors to control circuits which are completed in accordance with a control logic provided to apply heating power to selected ones of the resistors to define a desired display pattern which may be varied in color and tone according to the heating temperature set by a power regulator. Vanadium dioxide thermal elements, each contacting an end of a respective resistor, upon reaching a threshold temperature, latch in a separate power circuit which continues to heat the resistors after the initial heating thereof.

17 Claims, 10 Drawing Figures
### FIG. 5

<table>
<thead>
<tr>
<th>CHARACTER</th>
<th>SWITCH NO. MAKE CONNECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a b c d e f g h i j k l m n o p</td>
</tr>
<tr>
<td>1</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>2</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>3</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>4</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>5</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>6</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>7</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>8</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>9</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>0</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>A</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>B</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>C</td>
<td>x   x   x   x   x   x   x   x</td>
</tr>
<tr>
<td>ETC.</td>
<td>x</td>
</tr>
</tbody>
</table>
FIG. 8

THERMAL RESISTIVITY TRANSITION OF VO₂

RESISTANCE

10⁻⁴

20°  40°  60°  80°  100°

TEMPERATURE

FIG. 9

INVENTOR
Robert Marshall

ATTORNEY
3,848,245

1

QUENCHED PHOTOLUMINESCENT DISPLAYS AND A POWER CIRCUIT LATCHING MEANS THEREFORE

CROSS REFERENCE TO A RELATED APPLICATION

This is a continuation-in-part of my prior copending application Ser. No. 885,239, filed Dec. 15, 1969.

BACKGROUND OF THE INVENTION

A variety of illuminated displays, providing indicative characters and the like for data readout systems, are available. Vacuum and gas tubes are commonly utilized, for example the cold cathode neon glow discharge tubes and cathode ray tubes. Where the advantages of solid state components may be desirable, solid state displays have been provided from discrete light emitting diodes. In some cases a solid state display in a flat panel configuration has been achieved by utilization of electroluminescence.

Although a variety of illuminated display types are available, drawbacks are present and not in keeping with advances in economic, low power solid state switching circuitry. In some readout systems it would be extremely advantageous to control the associated illuminated display with integrated circuitry logic, such as by an economical metal oxide semiconductor (M.O.S.) module, and the like. Unfortunately, present displays capable of producing reasonably high light intensities require operating current levels incompatible therewith.

A solid state display in a flat panel configuration provides additional advantages such as being acceptable to economic batch manufacturing techniques. Also, the flat configuration obviates such difficulties as the size and depth limitations of cathode ray tubes and filament sach which distorts characters formed thereby in vacuum tubes of the incandescent type. While light emitting diodes provide advantages associated with solid state components they become prohibitively expensive in large flat panel configurations. Furthermore, the diodes provide a limited color choice and by nature produce light in concentrated areas which is unacceptable in many applications. A solid state flat panel display by utilizing electroluminescent phosphor proves to be of limited use because of low brightness, and short operating life together with A.C. voltage and complex control circuitry requirements.

While photoluminescent phosphors have long been noted for their brightness, as well as variety in color and tone, it has generally not been considered practical to provide photoluminescent data display devices because of the lack in the prior art of suitable means for selectively defining characters on the phosphor display surface and controlling the color and tone thereof in response to readout system signals. Means adapting photoluminescent display panels for multiplex control operation have likewise been unattainable heretofore.

Write-in capability, that is illuminated display by manually writing or drawing on a display surface, would also be desirable, however, heretofore has been unavailable in the abovementioned display types.

SUMMARY OF THE INVENTION

To overcome the foregoing and other difficulties of the prior art, the present invention contemplates the provision of a photoluminescent display by the quenching of excited luminescent material through application of heat thereto in selected areas to define a desired display pattern. To this end, a flat planar display panel is provided having a plurality of separate and spaced thin film resistors bonded onto the surface of a substratum, such as a printed circuit board, glass, or other electrically and thermally insulative material. Thin film conductors are provided for individual connection of each resistor to a control circuit. A phosphor layer overlies the surface of the substratum as well as the resistors and conductors. The layer may be made up of either one or a plurality of several phosphor compounds each having a different luminescent color and quenching temperature range characteristics. Light rays are directed onto the phosphor to excite luminescence therefrom. A heating current is then caused to pass through selected control circuits and resistors to heat areas of the phosphor and quench luminescence thereat to form a display pattern, such as a readout character. A power circuit, separate from the control circuits, may be provided with a thermal switch means which latches upon reaching a threshold temperature to provide heating current through the selected resistors after the selected control circuits are opened. The thermal switch means, in accordance with the present invention, may be provided by individual elements, each contacting an end of a respective resistor, and each of a material having the property of abruptly changing electrical resistance at a given temperature, for example, vanadium dioxide (V2O). If desired, a heated pointer may be used to trip the thermal switch means independently of control circuits, by manually writing or drawing with the pointer on the excited luminescent surface to quench luminescence in a desired pattern, and in this manner, providing a write-in capability. On the other hand, multiplex control for character selection is feasible by virtue of the separate power circuit and latching means therefore. A power regulator provides a range of heating temperatures to be selectively produced so as to provide a variety of colors and tones.

Thus, one of the objects of this invention is to provide an electrically controllable photoluminescent display.

It is an object of this invention to provide a flat panel solid state display for readout systems.

Another object is to provide a display which is economical and durable in operation.

Still another object is to provide a display panel of low cost.

Yet another object of the present invention is to provide a photoluminescent data display apparatus in which both the color and tone of displayed data indicia may be electrically controlled.

Also, an object of this invention is the provision of a display system adaptable to either A.C. or D.C. operation at relatively low voltage and current levels.

Yet another object is the provision of a solid state display panel requiring a simple control circuitry and operable at low D.C. voltage and current levels compatible with metal oxide semiconductor (M.O.S.) integrated circuitry logic.

An object of this invention is the provision of a display of illuminated characters selected through electrical control circuits and powered by a separate circuit.
having means to latch in an “on” condition after the control circuits turn off.

It is an object to provide an illuminated display having write-in capability allowing the creation of various display patterns by manually writing and/or drawing on the display surface.

Also an object is the provision of a photoluminescent display apparatus which is readily adaptable to multiple control operation.

Furthermore, it is an object to provide a display panel susceptible to economic mass production and batch fabrication techniques.

Further and other objects of the present invention as well as a more complete understanding thereof may be had by referring to the following description taken in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the present invention, there are shown in the drawings various forms thereof, which are presently preferred, it being understood, however, that this invention is not necessarily limited to the precise arrangements and instrumentalities there shown.

FIG. 1, is a schematic and partially cut away plan view of an elemental display device of the present invention.

FIG. 2, is a cross-sectional view of the device shown in FIG. 1 taken along line 2—2 thereof.

FIG. 3, is a partial schematic perspective view in cut away portions, illustrating a typical display panel of the present invention and elemental control circuitry therefore.

FIG. 4, is a partial sectional view of the display panel shown in FIG. 3 taken in the direction of the arrows 4—4 thereof showing by dashed lines typical conductor paths on the reverse side of the display panel.

FIG. 5, is a logic diagram exemplifying the manner in which the display of characters may be controlled on the display panel shown in FIGS. 3 and 4.

FIG. 6, is a schematic view showing an enlarged portion of an alternate display panel embodiment with power circuit latching means, together with simplified versions of associated circuitry therefore.

FIG. 7, is a cross-section of the display panel shown in FIG. 6 taken along line 7—7 thereof.

FIG. 8, is a graph illustrating the temperature-resistance relationship of latching means according to the present invention.

FIG. 9, is a schematic perspective view of an alternate display panel embodying the present invention and illustrating the write-in capability thereof.

FIG. 10, is a schematic perspective view showing a portion of an alternate display device embodiment wherein the luminescent display panel and the source of excitation are in a single integrated package.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, where like numerals indicate like elements, there is shown in FIGS. 1 and 2 an illustration of an elemental display device of the present invention indicated generally by the numeral 10. The embodiment of FIGS. 1 and 2 is simple and of limited application, however, it discloses the basic principles of the invention. The display device 10 includes a display panel 15 which has a substratum 20 providing a support surface at 25. The substratum 20 is provided by a flat planar sheet of material of low thermal and electrical conductivity and, preferably, having chemically inert properties, such as glass. Boards used in printed circuitry are also suitable material for substratum 20 and provide fabrication advantages, as will become apparent. Almost any size and shape may be chosen for the substratum 20, according to a desired display design. Furthermore, it is understood that the substratum 20, and display design need not necessarily be only flat and planar.

A thin film resistor 30 is bonded onto the surface 25. A chemical-mechanical bond may be accomplished between the materials of substratum 20 and resistor 30 by well-known processes such as vacuum evaporation and chemical vapor deposition. Requisite properties of the materials of resistor 30 and substratum 20 are that they be susceptible to durable inter-bonding and have compatible coefficients of expansion so the bond remains intact over an operating range of temperatures. In addition, the material of resistor 30 should be of a high thermal conductivity and be inert chemically to luminescent materials. Semi-metallic alloys such as tin oxide (SnO₂) and chromium silicide (CrSi₂) are suitable, and the latter is preferable. Thickness of the thin film of resistor 30 may be about a micron to provide high resistivity and low thermal mass for quick response and limited heating power requirements. The area shapes of the resistor 30 may be determined by standard microcircuit fabrication methods, such as photolithography or metal masking techniques. The shape of the resistor 30 in FIG. 1 has been chosen to define an elongated rectangle representing a numeral one. Naturally, other characters and shapes may be chosen.

Conductor means of panel 15, for supplying electrical heating power to the resistor 30, is provided by a thin film of conductive material deposited on surface 25 to define conductor paths 40. Opposite ends of the resistor 30, as shown at 32 and 33, have good electrical contact with the conductor paths 40 and are connected therethrough to a control circuit 45. Control circuit 45 includes a power source 46 and switch 48, which are connected in series with resistor 30, as shown. The switch 48 may be opened and closed to conditionally apply heating power to the resistor 30, as desired. Power regulator means may be provided in circuit 45 by a rheostat 49, or the like, for control of the heating current supplied by source 46. The conductor paths 40 are also bonded onto the surface 25, for example by vacuum deposition. Again the materials of the conductor paths 40 and of the substratum 20 have properties providing a durable bond therebetween and have compatible temperature expansion coefficients. It is important that the material of conductor paths 40 also have chemical inertness to luminescent materials, have low electrical resistivity, and be easily solderable or weldable. The conductor paths 40 may be shaped to provide terminal areas 41 to facilitate connection into a circuit by reception between spring contacts (not shown) or by soldering and the like. Film thickness of approximately one micron may be preferred in order to limit the heat sinking potential with reference to resistor 30. Thin films of nickel-chromium (Ni-Cr) or nickel and chromium noble metal alloys, such as nickel-gold (Ni-Au), chromium-gold (Cr-Au) are suitable for forming the conductor paths 40.
Separate thin film metal heat sinks 50 may also be provided, in close proximity, as shown, to the edges of resistor 30 and paths 40. Heat sinks 50 have no contact with resistor 30, paths 40 or the circuit 45, but rather provide a heat absorption sink separated from resistor 30 and paths 40 by a narrow gap 51. The material of heat sinks 50 may be identical to that of the conductor paths 40 and all may be deposited together on surface 25 and separately defined thereon by photolithography or metal masking techniques. The area and film thickness of heat sinks 50 may be chosen according to the thermal mass desired, however, for ease in manufacturing, the thickness of the heat sinks 50 is preferably the same as for paths 40. For reasons that will become more apparent hereinafter the heat sinking potential of the conductor paths 40 is also a factor to be considered in determining the amount of power required to form a desired pattern on the display surface and the speed with which the pattern may be effectively switched "on" or "off." By restricting the area and thickness of conductive paths 40, thermal mass may be reduced and thereby reduce power requirements. It may be desirable to increase the heat sinking potential of paths 40 by enlarging their areas and thickness, for example in applications where a quick heat cycle response period may be desirable. It is, of course, important that the area and film thickness of paths 40 be chosen accordingly.

A luminescent display surface is provided by a phosphor layer 60 overlying the surface 25, resistor 30 and conductor paths 40. The phosphor is applied to the substratum 20 in an even thin layer by doctor blading, spraying and/or other available batch processing techniques. Phosphor compounds including zinc sulfide (ZnS), zinc selenide (ZnSe) or zinc cadmium sulfide (ZnCdS) are suitable.

It is intended that a multitude of repeated display cycles can be accomplished by the invention over an extended period of time. This means a repeated heating and cooling of the resistors 30. For this reason it is essential that the bond to surface 25 of resistors 30, conductor paths 40 and heat sinks 50 remain intact. Furthermore, there be no deterioration of the thin film materials on the surface 25 by chemical reactions with phosphor layer 60, or vice versa. Also, the insulating materials of substratum 20 must insulate thermal and electrical isolation of the resistor 30.

Radiation means for exciting luminescence of the phosphor layer 60 may, in accordance with the present invention, be a mercury discharge lamp 70 of a well-known type which is energized by a source of power (not shown). Ultraviolet rays of the lamp 70 are emitted onto the phosphor layer 60 to excite luminescence thereof. As is shown in FIG. 2, several lamps 70 may be mounted near the edges of panel 15 and include reflectors 72 to provide edge illumination thereof.

In the operation of the embodiment of the present invention shown in FIGS. 1 and 2 radiation of ultraviolet rays from the lamps 70 onto the phosphor layer 60 excites the phosphor and produces a bright and uniform luminescence over the entire surface of the layer. Heating means for quenching a selected area of luminescence at phosphor layer 60 are provided by circuit 45, conductor paths 40 and resistor 30. Switch 48 is closed to cause a current flow from source 46 through the circuit 45 and conductor paths 40, to heat resistor 30. In accordance with the present invention, heat from the resistor 30 at the overlying phosphor 60 acts to quench the luminescence thereof in a pattern defined by the area of resistor 30 to thereby produce a dark numerical indica "1" against an illuminated background. Particles of phosphor near the edges of the resistor 30 can, of course, also become heated and thereby tend to provide a fuzzy edge for the display pattern. However, in accordance with the present invention, heat sink 50 absorbs heat at or near the narrow gap 51 to sharply delineate a display edge.

A particular luminescent color at layer 60 may be provided by combination of several phosphor compounds, much in the manner that white, blue, etc. light is achieved in the common fluorescent lamps. That is, as is well known, proportions of the primary colors red, blue and yellow, may be blended in an even uniform particle dispersal to provide a particular color sensation to the human eye. Phosphor compounds of different colors may be provided by a basic phosphor system, such as a zinc cadmium sulfide selenide host with copper or silver chloride [(Zn, Cd, CuS) or (AgCl)] providing activator, coactivator balance. The color of each compound is dependent primarily on the activator type and concentration but has a secondary dependence upon the composition of the metallic component of the system, that is, (Zn, Cd, Cu). As a specific example, for an activator concentration of 10*gm/gmZn, a green color is provided by the compound having the composition Zn_{50} Cd_{30} S: AgCl. A greater proportion of cadmium in the metallic component will produce a red color. Zinc sulfide: silver chloride (ZnS:AgCl) provides blue color, achieved by elimination of cadmium in the metallic component. Each phosphor color compound may be utilized alone to form layer 60. It is desirable, however, to provide a particular luminescent color, such as white, by several different compounds, blended in appropriate proportions. The individual crystalline phosphor particles are symbolically represented in FIGS. 1 and 3 by a circle (o), a square (Q) and a cross (+). Thus, a blue color particle is shown at 61, a red particle at 62, and a green particle at 63. The dispersal is even and uniform and in a proportion yielding a desired color, say white luminescence. It is understood, of course that the particle reaction and the phosphor composition are such that the particles actually being much smaller than the symbols employed to diagrammatically depict the same in the drawing.

It has been observed that photoluminescent phosphor compounds have characteristic ranges of luminescent quenching temperatures. That is, when the phosphor is excited into luminescence as for example by subjecting the same to radiation from a source of ultraviolet light, the intensity of the luminescence will gradually decrease as the temperature of the phosphor is raised through a specified range of temperatures. For example, the compound Zn_{50} Cd_{30} S: AgCl will gradually quench from bright green, to dull green, to green gray, to gray, to black, as the temperature is increased from 950° C to 1050° C. The temperature ranges of the compounds provided by the aforementioned basic phosphor system are found to be determined by the composition of their anionic component (S_{n}Se_{m}). An increase in the selenium proportion has been found to lower the quenching temperature range. Phosphor compounds may be therefore made to have different quenching temperature ranges as well as different color characteristics. Thus, it is to be understood, that the
phosphor layer 60 may be a blend of phosphor particles 61, 62, 63, of several phosphor compounds having different characteristics as to both color and quenching temperature ranges.

The power regulator means provided by rheostat 49 may be adjusted to provide a desired temperature at resistor 30, within the temperature quenching range of a particular phosphor compound provided at layer 60. If only a single phosphor compound is present, or if several are present, all with the same quenching temperature range, then regulation of the temperature will vary the gray scale tone. On the other hand, if several phosphor compounds, each of a different color and of a different quenching temperature range, are present at layer 60, then changes in both tone and color sensation may be accomplished by regulation of the temperature. That is, it may be appreciated, that the temperature may be regulated for quenching of a single color, or several colors, simultaneously or in succession, as well as in gradations of tone to provide a variety of color sensations ranging from white to black, with intermediate colors and tones thereof.

While the regulator means are shown as a simple rheostat, it is clear that this is rather primitive, and that other, more sophisticated means could be substituted. Regulation by transistor, or other control devices, can be readily envisioned by those skilled in the electronic art to provide power regulation in response to signal impulses or the like.

A typical panel 15', which provides display characters in response to a logic drive, is shown in the views of FIGS. 3 and 4. Although the panel 15' may appear somewhat complex, it operates on the same basic principles already described. A substrate 20' provides a support surface 25' and is of a thermally and electrically insulative material such as that commonly used for a printed circuit board. FIG. 3 shows a part of panel 15' in three, cutaway portions. A portion at the left hand one-third of FIG. 3 has been cut away to completely reveal surface 25', and the connections through substrate 20'. A middle-third portion of the drawing illustrates the pattern of thin film depositions on the surface 25'. A portion at the right side of FIG. 3 shows the panel 15' in its finished form covered by a phosphor layer 60'. It is to be understood that the various elements of the above described portions of FIG. 3 are identical and are referred to by the same numerical references.

A plurality of characters may be provided on the panel, for example three separate characters, one for each of the adjoining portions described above. Each character is formed by a plurality of individual resistors 30' which are spaced apart upon the surface 25' in a matrix providing segments adaptable to a plurality of different character shapes. As shown, the individual resistors 30' may be uniform in size and shape, for example, each of an area defining a square. Naturally, other geometric shapes would be equally acceptable. Film thickness and materials of resistors 30' are as previously described. Individual resistors 30' may be spaced and aligned in vertical columns and horizontal rows to form the matrix illustrated, which resembles a rectangular numeral eight. Segments of the matrix, formed by a single resistor 30' and by banks of two or three resistors 30', may be selectively quenched to define a variety of letters and numerals. On the other hand, matrix forms different than the one shown may be provided for more complex display patterns, if desired.

As is indicated at the right-hand third of FIG. 3, a phosphor layer 60' overlies surface 25', resistors 30' and conductive paths 75–90. The materials of layer 60' may be as previously described. Preferably, blue particles 61', red particles 62', and green particles 63', of phosphor compounds having different quenching temperature ranges, are blended in an even, uniform dispersal, and in proportions to provide a desired lumenescence color.

Conductor means are provided by a plurality of thin film conductor paths 75–90 having good electrical contact at opposite sides of resistors 30'. Conductor paths 76 are common at one side of all resistors 30'. Conductor paths 77, 79, 80, 81, 82, 84, 86, 88, 89 and 90 each contact a separate, single resistor 30', respectively, at a side opposite to that in contact with the common conductor paths 76. Conductor paths 78, 83, 85 and 87, each contact several resistors 30' in banks of two or three, as shown, at sides opposite to that in contact with common conductors 76. Conductor paths 77, 78, 79 and 84, 85 and 86 extend directly out to the edges of the panel 15', as shown. The remaining conductor paths 75, 76, 80, 81, 82, 83 and 87, 88, 89, 90 have continuation paths, indicated in FIG. 4 by identical primed reference numbers, on the reverse side of panel 15' leading to the panel edges. Connector pins 95, 96, 100, 101, 102, 103, 107, 108, 109 and 110 pass through the substratum 20' to connect respective conductor and continuation paths. That is, for example, pin 95 connects conductor path 75 to its respective continuation path 75' on the reverse side of panel 15'. Thus, pins 96, 100, 101, 102, 103, 107, 108, 109, 110, connect respectively between conductor paths 76, 80, 81, 82, 83, 87, 88, 89, 90 and their counterpart continuation paths indicated by identical but primed numeral.s. The connector pins may be solid when inserted through the substratum 20' or may be formed by electro-through plating of openings bored through the substratum 20'. It is to be understood, of course, that the resistors 30', and the conductor paths and counterpart continuation paths, are thin films of materials which have already been described above for the elemental embodiment shown in FIG. 1 and may be deposited by the same processes. Electrical contact between the pins and conductor paths may be accomplished by the simple deposit of the thin film material over ends of the pins. Edge connection to the ends of each conductor path, may be accomplished by insertion between well-known spring contacts (not shown) or by soldering or the like.

Ends of each individual conductor path are connected by a separate individual switch (a–p) to a control circuit 45'. For ease in tracing the individual circuits of each resistor 30' the end of each conductor path and each respective switch have both been indicated on the drawing by the same letter (a–p). The switches (a–p) connect each conductor path into the circuit 45' in series with the power source 46'. Thus, it can be understood, that by closing selected of the switches (a–p) power is applied to desired ones of resistors 30'. In this manner, various segments of the matrix formed by resistors 30' may be heated and luminescence quenched accordingly at phosphor layer 60 for formation of a particular character. The logic diagram of FIG. 5 demonstrates which of the switches (a–p)
must be closed to form a particular character. The character drive logic may be quickly determined from the
diagram of FIG. 5 by following the horizontal row of X's adjacent a chosen character and reading appropriate
switches identified by letters (a-p). A random example, the numeral three may be formed by closing
switches (a), (c), (e), (f), (g), (h), (k) and (l). Switch (a) connects one side of the power source 46' to
continuation path 76', and through connector pin 95 to both common conductor paths 76. Since the conductor
paths 76 are common to all characters, switch (a) may be left permanently closed. Switch (c), when closed,
connects the opposite side of power source 46 to conductor path 78. The circuit is completed through the
bank of three resistors 30' between paths 76 and 78, for formation of the top segment of the numeral three.
That is, current will flow through the appropriate resistors 30' and heat the phosphor layer 60' immediate thereto.
Switch (e) closes a circuit connecting the power source 46' to continuation path 80' and through connector pin 100 to conductor path 80. Thus power is applied to the individual resistor 30' between
circuit path 80 and common conductor path 76. That heat and quench another area of phosphor layer 60' to form
another portion of the chosen numeral. Similarly, it is clear that closing of the switches (f), (g), (h), (k) and
(l) will apply heating power to the resistors 30' between common paths 76 and paths 81, 83, 75, 85 and
86 to complete the numeral three.

Power regulator means, symbolized by rheostat 49', may be utilized to control temperature at resistors 30
and provide color and tone as previously described. Of course, it is to be understood, that the control circuit 45'
and its various switches (a-p) are likewise a primitive control means which may be manually operated to
provide a variety of characters. More sophisticated controls are envisioned for the display panels of this
invention. Metal oxide semi-conductor integrated circuit logic control modules (not shown) are available and,
as will be understood by those familiar with readout devices, may be appropriately connected to ends of the
conductor paths to provide a drive logic responsive to a readout system and the like. Similarly, a regulator module
can be provided to control resistor temperature in response to a readout system signal. In such cases, it may be desirous to redesign the conductor path layout for direct mounting of integrated circuit logic modules on the back side of panel 15'.

Multiplex control operation for selection of display characters and/or write-in capability allowing display
by manually writing and/or drawing on a display surface, may be readily achieved by utilization of power
circuit latching means in accordance with the present invention, which are described herein with reference to
FIGS. 6 through 9. Attention is first directed to FIG. 6, which shows an enlarged portion of a display panel 115
having a substratum 120 defining support surface 125. Thin film resistors 130 and thin film conductors 140,
142 are bonded onto the support surface 125. As shown in the figure, the resistors 130 are connected across the conductors 140, 142. Note that the conductors 140 provide separate individual paths to each resis-
tor 130, while the conductor 142 is common to all resistors 130. Thermal switching elements 150 are pro-
vided at the end of each resistor 130 opposite to that of the common conductor 142. As may be best seen
with reference to FIG. 7, switch elements 150 are bonded directly on surface 125 at positions underlying the
resistors 130. A connecting pin 152 through the substratum 120 connects each switch element 150 to a
common conductor 155 which is bonded on the opposite side of the substratum 120. A phosphor layer 160
overlies the surface 125, resistors 130, conductors 140, 142 and switch elements 150, as shown on the enlarged
cross-section of FIG. 7.

It is to be understood that the materials of the substratum 120, resistor 130, conductors 140, 142, 155,
connector pins 152, and phosphor layer 160, as well as the manner of bonding to the substratum 120, are identi-
tical to that of the display panel embodiments de-scribed previously, and no further description thereof is necessary. However, the switch elements 150 are of
a material having special thermal properties which provide a latching means in accordance with the present
invention. Materials such as vanadium dioxide (VO2)
which exhibit a negative thermal resistivity transition upon reaching a given temperature may be used to
provide latching means in accordance with the present in-
vention. As illustrated in the graph of FIG. 8, there is an abrupt change in the resistivity of the thermal
switching material upon reaching a threshold tempera-
ture. As is indicated by the almost vertical drop of the graph's curve, vanadium dioxide undergoes an abrupt
device in resistivity at about 60°C. The change in re-
sistivity is rather extreme, amounting to four orders of
magnitude, from 10⁴ to 10⁻⁴ ohm cns. This property of
vanadium dioxide may be taken advantage of in accord-
cance with the present invention, to provide resistance which is relatively high when below a threshold tempera-
ture to limit heating current to levels insufficient to
cause substantial quenching of luminescence, yet to
provide resistance which is relatively low when above
the threshold temperature to permit heating current levels sufficient to cause quenching. In effect, the
property provides a thermal switching means. Other materi-
als are available which also exhibit negative thermal re-
sistivity transitions over different temperature thresh-
olds and over greater orders of magnitude. A full dis-
cussion of this phenomenon is set forth in the scientific papers of G. P. MacChesney, G. F. Potter, and H. J.
Guggenheim, J. Electrochem., Soc. 115, 52, 1968; and
Soc. 115, 56, 1968. Thus, it is to be understood that
materials other than vanadium dioxide may be utilized in accordance with the present invention, depending
upon the desired thermal resistivity transition character-
istics desired. Reactive sputtering or chemical vapor
deposition techniques may be utilized to provide a film
of less than 1000 Angstroms on surface 125 in defini-
tion of each switch element 150. As an example, the
switch element 150 may have a length to width ratio of
2 to 1, say .025 x .05 inch for a thickness of 1000 Ang-
stroms. These dimensions of a vanadium dioxide mate-
rial will provide resistance values which abruptly change from approximately 20,000 ohms to 2 ohms at
about 60°C. For a supply voltage of 20 volts and 2000
ohm resistor 130, a current level of 10 milliampere
will provide full quenching heat, through the negligible
2 ohm resistance of a switch element 150. On the other
hand, when resistance of the switch element is at
20,000 ohms, current at 20 volts will be limited to less
than a milliampere, which is insufficient to provide
quenching heat.
A separate power circuit indicated generally by the numeral 170 is connected to supply heating current through the common conductors 142, 155, connector pins 152 and thermal switch elements 150, as shown in FIG. 6. The power circuit 170 includes a power source indicated schematically at 173 and a switch 175.

Simplified multiplex control circuitry is indicated on FIG. 6 generally by the numeral 180. It is to be understood, that the rudimental circuitry shown is merely for illustrative purposes and that far more complex circuitry is well known in the multiplex art and is envisioned in accordance with the present invention to provide signal impulses for selection of desired characters. The simple multiplex control circuitry 180 of FIG. 6 includes commutators 181, 182 which are synchronously driven by the motor-clutch devices 183, 184. The commutator 181 has a rotary contact 185 driven by a coupling indicated at 187 to motor-clutch 183. In a like manner, the commutator 182 has a rotary contact 186 driven by a coupling 188 to motor-clutch 184. A series of individual switches identified by the small case letters (t-z) connect one side 196 of a separate power source 190 to contact points on commutator 181, identified by identical but primed letters (t'-z'), respectively. Contact points of the commutator 182, corresponding to those of commutator 181 (t'-z') and the individual switches (t-z), are indicated by identical but double primed letters (t''-z''). Notice that the contacts (t''-z'') are each connected to an individual conductor 194. The rotary contacts 185, 186, of each respective commutator 181, 182, are electrically connected as indicated by line 195.

A synchronous start and single cycle operation for the motor-clutches 183, 184 may be provided by instantaneous switch 197 and parallel rotary switch 198 which connect the motor-clutch devices 183, 184 to one side 196 of the power source 190. As shown, the stationary contact element of rotary switch 198 engages a rotary contact 199 which is coupled for drive by the shaft 187. A stop contact point 200 and a start contact point 201 are provided at the ends of the stationary contact element of rotary switch 198, as shown. It is understood that the two occurrences on the drawing of the numeral 196 represent points common to one side of power source 190. The other side of source 190 is connected to a common ground.

Multiplex operation of circuit 180 is as follows. Selection of the switches (t-z) are closed in accordance with a control logic similar to that described beforehand to heat selected resistors in definition of a desired display character. Switch 175 of the power circuit 170 is also closed, however, current flow is limited by the relatively high resistance of switch elements 150 to levels insufficient to provide heat for substantial quenching of luminescence. Instantaneous switch 197 is temporarily closed to initiate simultaneous operation of the motor-clutch devices 183, 184 by completing a circuit therethrough from side 196 of the power source 190 to ground. Rotation is transmitted through couplings 187, 188. Rotary contact 199 rotates clockwise to engage the start contact point 201. Thereafter, energizing power for the motor-clutch devices 183, 184 is provided through a circuit from side 196 of source 190 through rotary switch 198 to ground. This circuit continues to supply operating power after the instantaneous switch 197 has opened. Operation of the motor-clutch devices 183, 184 will continue until the rotary contact 199 makes one complete rotation past stop contact point 200 where the circuit is open. In this manner it is understood, both motor-clutch devices 183, 184 are energized to provide one complete and simultaneous revolution of the commutators 181, 182. Assuming for purpose of illustration, that switches (w), (x), (y), and (z) are closed, clockwise rotation of commutators 181, 182 makes corresponding contact points (w'), (x'), (y'), (z') and (w''), (x''), (y''), (z'') pass an impulse signal therethrough. That is, for instance, when rotary contacts 185, 186 pass their respective contact points (w'), (w'') there will be a momentary flow of current from side 196 of power source 190 through the closed switch (w) to contact point (w'') through rotary contact 185 and line 195 to rotary contact 186 to contact point (w'') and to a conductor 140 across a resistor 130 to common conductor 142 to ground at 143. The current flow will be momentary, but sufficient to raise the temperature of thermal switch element 150 above its thermal resistivity threshold temperature. The commutators 181, 182 continue the rotation cycle and make the remaining contact points (x', y', z') and (x'', y'', z'') in a similar manner. Once heated above the thermal resistivity threshold temperature, the individual thermal switch elements 150 become, in effect, relatively low resistance conductors to latch in the separate power circuit 170. Power circuit 170 will continue to supply heating current through common conductors 142, 155, the heated switch elements 150, and their associated connector pins 152 and resistors 130, until switch 175 is opened. On the other hand, as to unselected resistors 130 of open switches (t), (u), (v), they will remain quiescent as long as thermal switch elements 150 are in a cool status and acting as relatively high value resistors. In this manner, it is understood that multiplex control operation for each rotation cycle of commutators 181, 182, may be effected by sending momentary heating current pulses through line 195 to raise the temperature of selected thermal switches 150. The latching means, provided by thermal switches 150, in accordance with the present invention, thereafter maintain the power circuit 170 in an "on" condition for each of the selected resistors 130.

Note that the initial heating current need not necessarily be supplied by the multiplex control circuit 180, as it is clear that any source of heat may be applied to raise the temperature of switch elements 150 above their resistivity transition threshold. Thus, with reference to FIG. 9, it may be visualized that the latching means of the present invention presents a display panel with write-in capabilities. There, a luminescent display panel 215, in accordance with the present invention, has a complete solid array of individual resistor elements 230, arranged in rows and columns, each with power circuit latch means provided by thermal switch elements and connected to a power source as previously described. Again the resistor elements 230 are covered by an overlay of luminescent material. The pointer 240 has a heated tip 245, which may be provided by an electrical resistor element therein, connected to a source of heating power 247 by closing the switch 246. As shown, various displays may be provided by drawing and/or writing with the pointer 240 to quench areas 250, as desired. That is, the hot tip 245 heats individual resistors 230 and the associated thermal switch elements as it passes over the luminescent
display surface. As described beforehand, the heated thermal switch elements latch a power circuit through respective of the resistors 230 in an “on” condition to quench an area of luminescence in definition of a described pattern traced by the pointer 240. In accordance with the write-in capability disclosed, it is easily understood that a variety of manual drawings and writings may thus be inscribed. As may be appreciated by those skilled in the computer art, the write-in information provided by the heated resistor elements may be applied through appropriate circuits as the input to computer memory circuits and retrieved as write-in output therefrom.

With reference to FIG. 10, an alternate display device embodiment, in accordance with the present invention, is indicated generally by the numeral 300, and has a display panel and source of excitation therefore in a single integrated package. The display device 300 is an electrical lamp having an enclosed enveloped 310 and plug terminals 316, 317 for connection to a source of electrical power, indicated schematically at 318. It is understood, of course, that the plug terminals 316, 317 are merely illustrative of a typical lamp connection and that other well-known connections would be equally suitable. Preferably, the lamp of device 300 radiates ultraviolet rays, as provided by typical mercury discharge lamps which are generally referred to as “black lamps.” The envelope 310 is of a glass or other suitable transparent material to provide an envelope for a vacuum discharge lamp. Preferably, the envelope 310 is of a glass material which has been dye-tinted to filter out visible radiation but to pass near ultraviolet light as is commonly done in the standard “black lamps.” A display substratum 320 defining the display surface 325 is formed at one side of the envelope 310, as shown. While the display surface 325 shown in FIG. 10 is flat and planar, it is, of course, understood that curved and other display surface shapes may be utilized in accordance with the present invention. It is noted that the remaining portion of the envelope 310 has a curved cross-section, which may be coated, either at the inside or outside thereof, with a reflective substance, such as aluminum, as indicated at 315.

A transparent thin film resistor 330 is adhered to the display surface 325. As described in the previous embodiments, the shape of the thin film resistor 330, or a matrix of many resistors, may be chosen to provide a desired character or display pattern. The numeral “2” shown on FIG. 10 is merely an example. Transparency in the thin film resistor 330 is provided by utilizing a deposit of transparent material, for example, tin oxide (SnO₂) or indium oxide (InO). It is known that sheet resistance of tin oxide may be adjusted by doping with antimony to provide a range from 10⁸ ohms per square to less than 300 ohms per square. Thus, an appropriate resistance may be chosen for the thin film resistor 330 to provide an electrical heating element which is readily formed on the glass substratum 320 by hot spraying techniques, or the like. Conductor paths are formed on the display surface 325 at opposite sides of the thin film resistor 330 by the pads 340 which may be of a conductive material as previously described for the other embodiments. Preferably, however, the pads 340 are also of a transparent material such as tin oxide appropriately doped with antimony to provide conductor paths having low sheet resistance with respect to that of the resistor 330. The thickness of resistor 330 and pads 340 may be on the order of the thin films already set forth in the other embodiments. The pads 340 are connected in a circuit, indicated schematically at 345, to a source of power 346. The circuit 345 may include a switch at 348 and power regulator means at 349, similar to that previously described, if desired.

The display surface 325, transparent resistor 330 and pads 340 are covered by an overlay of luminescent material 360, which may be of phosphor particles having temperature quenching and color characteristics as described beforehand.

Operation of the display device 300 is by connection of plug terminals 316, 317 to a source of electrical power 318 causing ultraviolet rays to be radiated from within the device 300. A portion of the rays will be reflected off surface 315 and through the transparent substratum 320 of the envelope 310. The luminescent overlay 360, including portions overlying the transparent resistor 330 and pads 340, will be excited to luminescence. The switch 348 may be closed to cause a current flow through the transparent thin film resistor 330 which will heat up and quench luminescence in definition of the character “2.” In this manner, the display and source of excitation therefore may be combined in a single integrated package.

The display examples described and illustrated herein have set forth a character or display pattern which is dark against an illuminated background. Naturally, it is understood that the reverse is also in accordance with the present invention. That is, it is understood that the character or display pattern may be illuminated against a dark background by providing the quenching heat at the background portion of the display pattern. Furthermore, it should also be recognized that the principles herein are not necessarily confined to photoluminescence, as the display panels can be self-illuminating for displays of low light intensity requirements. For example, it is well known that radioactive substances which are short range beta ray emitters, such as polonium, may be blended with the phosphor particles to provide luminescent excitation thereof. Again the display pattern may be defined, according to the present invention, by heating portions of the display to quench luminescence as described above.

While particular embodiments of the invention have been illustrated and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. A photoluminescent display device, comprising in combination:
a member having a display surface supporting photoluminescent material susceptible of excitation by electromagnetic energy to produce visible light;
means for directing electromagnetic radiation towards said display surface to excite luminescence of said photoluminescent material; and
heating means underlying selected areas of said photoluminescent material for quenching the luminescence thereof to define a desired display pattern thereon;
wherein the improvement comprises heat-actuated switch means in thermal contact with said heating
means and in electrical communication with an energy source and with said heating means, said switch means being actuated, by momentary increase of the temperature of said heating means to quenching temperature, to "on" state, wherein it feeds sufficient energy from said source to maintain said heating means at quenching temperature.

2. A device in accordance with claim 1 wherein said photoluminescent material is a dispersal of particles of several phosphor compounds having different color and quenching temperature ranges, and wherein said heating means comprises in combination an electrical resistance element in thermal contact with said photoluminescent material, and power regulator means for controlling the magnitude of electrical power supplied to said resistance element for thereby controlling the temperature thereof, to provide predetermined colors in the overlying photoluminescent material.

3. A device according to claim 1 wherein heat sink means are thermally coupled to said photoluminescent material around the periphery of said selected area to enhance the definition of said pattern.

4. A device according to claim 1 wherein said switch means includes resistor means for the dissipation of electrical power, said resistor means being variable in response to heat and limiting said dissipation to a quiescent level insufficient to quench luminescence when said resistor means are below a threshold temperature, yet passing said power for dissipation at a level sufficient to quench luminescence when said resistor means are above said threshold temperature.

5. A device according to claim 1 wherein said means for directing electromagnetic radiation comprise an electric lamp having an enclosed envelope, said envelope also providing said member and defining said display surface at an outside portion of said envelope for an integrated lamp and display package.

6. A device according to claim 5 where said portion of said envelope is transparent and where said heating means includes a transparent electrical resistance element on said display surface and under said photoluminescent material.

7. A device according to claim 6 where said resistance element is a transparent deposit of tin oxide.

8. A device according to claim 6 where said envelope includes reflective surfaces opposite said transparent portion to direct light therethrough from said lamp.

9. A photoluminescent display device, comprising in combination:

   a member having a display surface supporting photoluminescent material susceptible of excitation by electromagnetic energy to produce visible light;
   means for directing electromagnetic radiation towards said display surface to excite luminescence of said photoluminescent material;
   heating means comprising a plurality of separate and spaced electrical resistance elements positioned between said display surface and said photoluminescent material, and

   means for supplying electrical energy to selected ones of said elements to define a desired display pattern by quenching the luminescence thereabove, said last means including individual switch means in thermal contact with each of said resistance elements for limiting the dissipation of said energy therein to a quiescent level insufficient to quench luminescence when said switch means are below a threshold temperature, yet passing said energy at a level sufficient to quench luminescence when said switch means are above said threshold temperature, and control means for independently raising the temperature of said switch means above said threshold temperature at said selected ones of said resistance elements.

10. A device according to claim 9 wherein said switch means are provided by a material having the property of abruptly changing resistance at said threshold temperature.

11. A device according to claim 10 wherein said material is vanadium dioxide.

12. A display panel according to claim 9 wherein said resistance elements are a chromium silicide deposit.

13. A device in accordance with claim 9 wherein said control means includes multiplex circuit means for supplying momentary energy pulses to selected ones of said resistance elements to raise the temperature thereof, and thus raise the temperature of the associated switch means above said threshold temperature.

14. A device in accordance with claim 9, wherein said control means is constituted by a pointer with a heated tip for manual tracing over said display surface, thereby raising the temperature of such of said switch means as underlie the path traced.

15. In a display device having a display panel with a surface coating of thermally quenchable photoluminescent phosphor, a plurality of selectively energizable resistor heating elements underlying said coating and a plurality of conductors supplying electrical power for said resistors, individual thermal switch means at each of said resistors limiting the supply of electrical power to said resistors to a quiescent level insufficient to quench luminescence when said switch means are below a threshold temperature, yet passing power sufficient to provide quenching of the coating overlying a particular resistor when the switch means associated therewith is above said threshold temperature.

16. A display panel device according to claim 15 wherein said thermal switch means are provided by a thin filmed pad of material at one end of each of said resistors interposed between the resistor and certain of said conductors, said material having the property of abruptly changing in resistance at said threshold temperature.

17. A display panel device according to claim 16 wherein said material is vanadium dioxide.

* * * *