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**Pennebaker, Jr.**

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[54] **LOW VOLTAGE GAS DISCHARGE DISPLAY STRUCTURES FOR IMPROVED ADDRESSING**


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[52] **U.S. Cl.** ..... **313/217,** 315/169 TV

[51] **Int. Cl.** ..... **H01j 61/06**

[58] **Field of Search** ..... 313/188, 217, 109.5; 315/169 TV



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[57] **ABSTRACT**

A low voltage gas discharge display device wherein individual cells are addressed by three level and four level addressing techniques. In the "off" or standby state, low glow discharge occurs between an anode and a cathode, either or both of which are segmented so that the respective segments are common to groups of cells. In this state, with no pulses present control electrode lines, associated with rows of cells, are quiescently biased negatively to create a current impeding ion sheath across the respective cell holes therethrough to the positively biased collector electrode lines, associated with columns of cells. In a three level address scheme where only the cathode is segmented, the cathode segment containing a particular cell to be addressed is selectively driven negatively by a relatively short, partial-select pulse. During this negative pulse interval, partial-select positive pulses are also simultaneously applied to intersecting control and collector electrode lines including the lines which intersect at the cell to be addressed. In a four level address scheme, the anode is also segmented with the anode segments also being selectively pulse driven. Segmenting of the anode and cathode allows a reduction in the total number of drivers typically required in two level addressing of a given array of cells.


**6 Claims, 3 Drawing Figures**

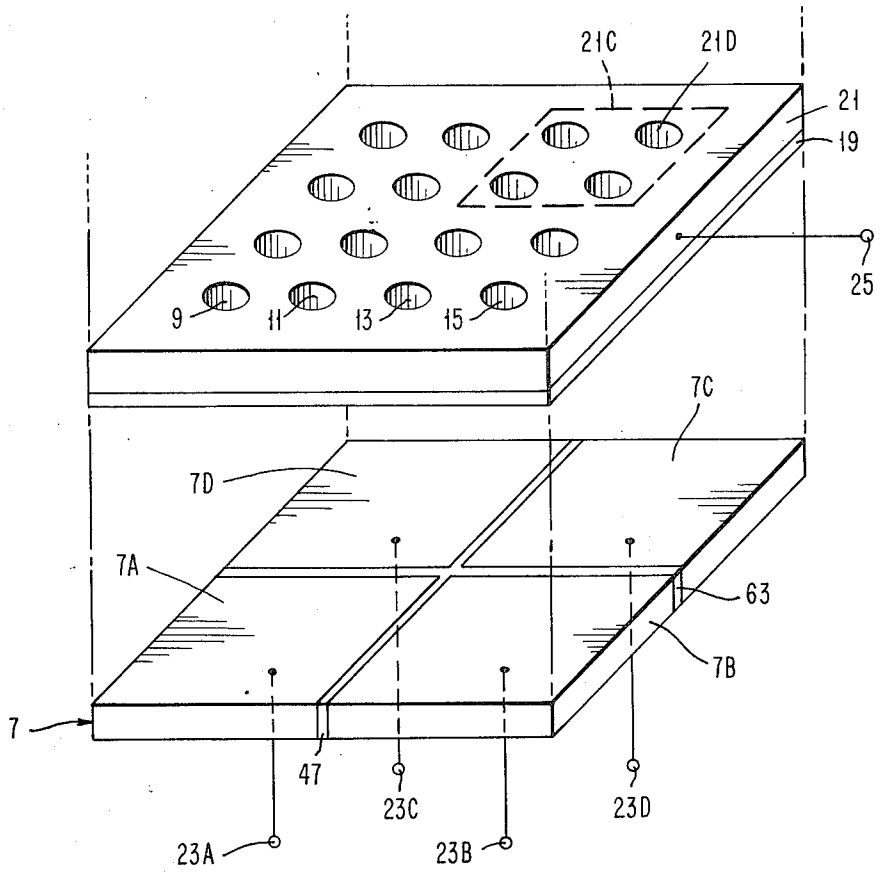


FIG. 1

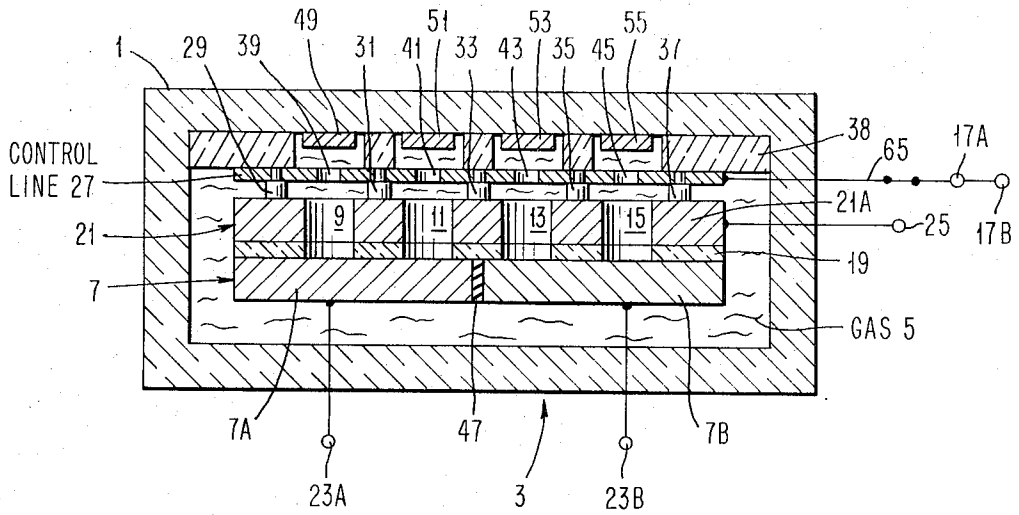

1
29
39
49
31
41
51
33
43
53
35
45
55
37
38
65
17A
17B
CONTROL LINE 27
21
21A
25
19
7
GAS 5
9
11
13
15
7A
47
7B
23A
3
23B

FIG. 3

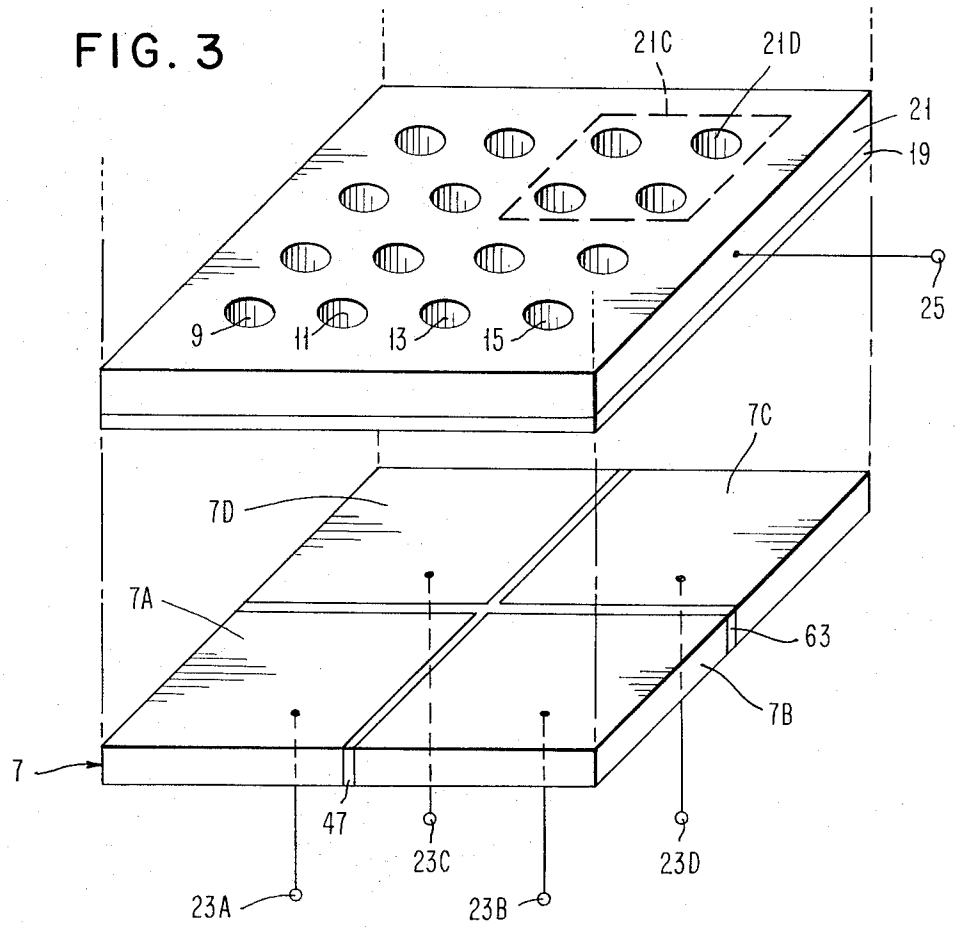
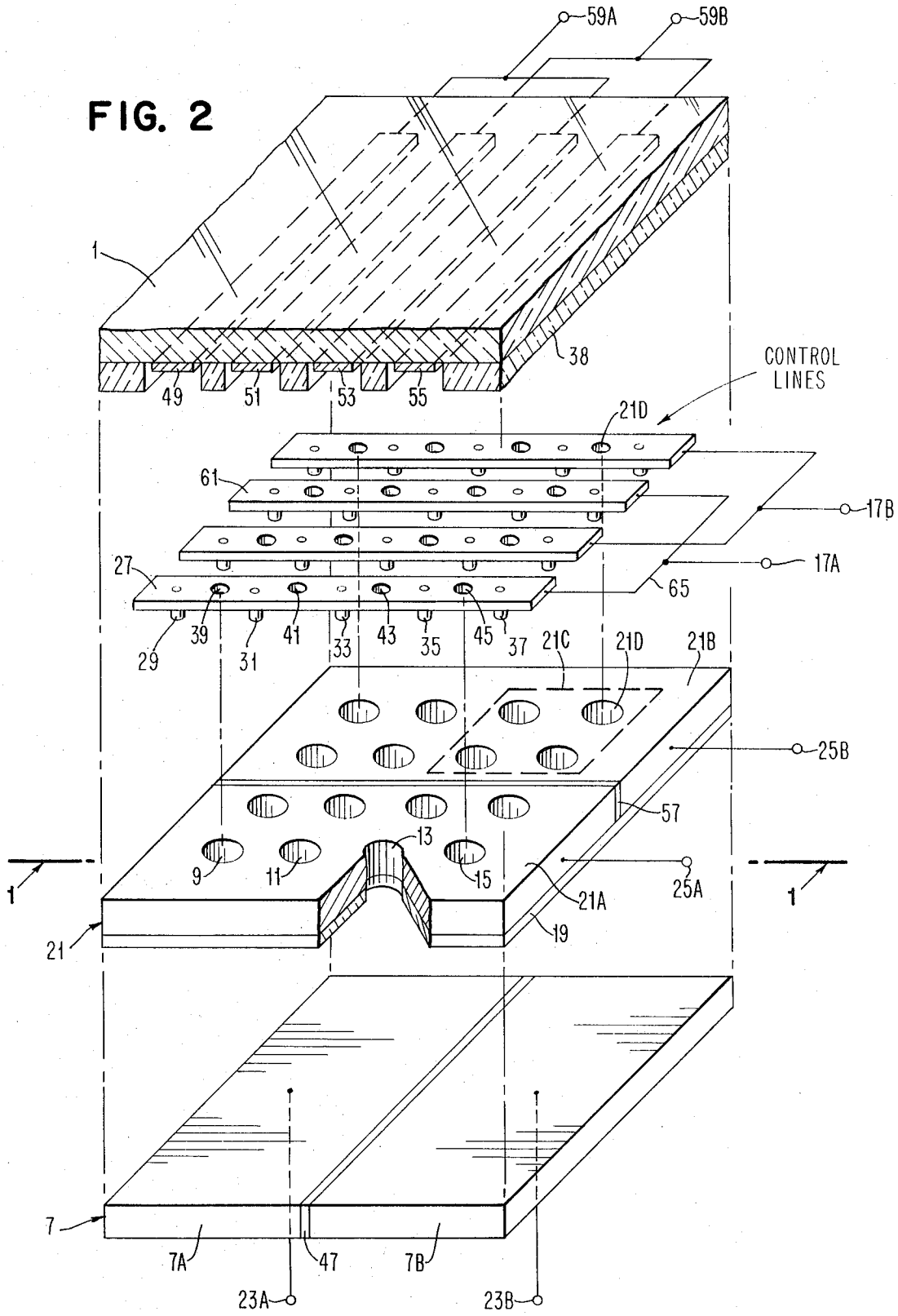

21C
21D
21
19
25
9
11
13
15
7C
7D
7A
63
7B
7
47
23C
23D
23A
23B

FIG. 2


59A
59B
1
38
CONTROL LINES
49
51
53
55
21D
61
17B
17A
27
65
29
39
31
41
33
43
35
45
37
21C
21D
21B
25B
57
13
9
11
15
21A
25A
19
21
1
1
7
7A
47
7B
23A
23B

# LOW VOLTAGE GAS DISCHARGE DISPLAY STRUCTURES FOR IMPROVED ADDRESSING

## CROSS REFERENCE TO RELATED APPLICATION

U.S. Pat. application Ser. No. 213,946, entitled "Low Voltage Gas Discharge Display," filed Dec. 30, 1971.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to low voltage gas discharge display devices and, more particularly, to arrangements for addressing low voltage gas discharge display devices whereby the number of drivers required to address such devices are at a minimum.

2. Description of the Prior Art

One of the drawbacks of prior art gas discharge display devices or panels resides in the fact that they typically require 80 volt (or more) pulses to drive the panel to selectively control information display thereon. Accordingly, the pulsing and driving circuitry required to selectively drive and control the a.c. gas panel, for example, is necessarily complex and costly. The above cited copending application is directed to overcoming the high voltage requirement by employing a four electrode arrangement, whereby the light from positive column glow discharge is used to selectively display information.

One of the elements in the complexity and costliness of drive circuits for display devices resides in the large number of drive circuits required. For example, in a typical two level half-select addressing scheme for a gas panel display arrangement, an array of $n \times m$ cells requires $n + m$ drive circuits for addressing. To reduce the number of drive circuits in a basically two electrode structure (such as the a.c. gas panel) is not readily achievable without making sacrifices in regard to simplicity and certain performance characteristics and capability. On the other hand, in gas panel display devices of the type described in the above cited copending application having basically more than two electrodes, the number of drive circuits required to address the device is not limited by the above mentioned $n + m$ requirement.

More particularly, in accordance with the principles of the present invention, by the prudent division or segmentation of the third and/or fourth electrode in three or more electrode gas discharge display devices, the number of drive circuits required to address such devices may be made optimally minimum. More particularly, by properly segmenting the area cathode and/or anode of a three or more electrode half-select addressed gas discharge display device, such as the low voltage gas discharge display device of the above cited copending application, the various segments of the cathode and/or anode may be selectively addressed and the number of half-select driver circuits heretofor employed in two level addressing the matrix of intersecting lines thereof may be substantially reduced.

## SUMMARY OF THE INVENTION

In accordance with the principles of the invention, in a preferred arrangement, a low voltage d.c. gas discharge display device is provided whereby light from positive column glow discharge is employed for purposes of addressable display. The preferred gas discharge display device arrangement of the present invention comprises an array of gas cells, with the individual cells of the array having at one end thereof, a first layer of conductive material which acts as a cathode electrode, electrically common to at least some of the cells. The cathode electrode is segmented into blocks or cathode segments which are electrically insulated from one another, whereby each block acts as a cathode electrode electrically common to all cells within the block. A second layer of conductive material, insulatively removed from the cathode layer and having a plurality of cylindrical holes therein which communicate with the said cathode layer, acts as an anode electrically common to at least some of the cells of the array, in a conventional manner. In addition to having the cathode segmented into blocks, the anode likewise may be segmented into blocks, the projections of which would tend to act to further segment cells common to the cathode blocks.

A third array of insulating spacers, or the like, act to insulate the anode layer from a plurality of opaque control lines, each control line being common to a particular row of cells in the array, and having holes therein of a smaller dimension than, and at locations corresponding to, the holes in the layer of conductive anode material. In addition, a further layer of insulating material acts to space the various control lines from a plurality of transparent conductive collector electrode lines, with individual ones of said plurality of collector electrode lines being common to the cells in the respective columns of said array of cells.

In accordance with the manner by which the cathode and/or anode is segmented, selected ones of respective control and collector electrode lines which are in registry with respective segmented blocks, may be electrically connected together. In accordance with such an arrangement, when a particular cell within a given segmented cathode block is to be addressed, simultaneous pulses are applied to the appropriate control and collector electrode lines which intersect at the appropriate cell to be pulsed. Since corresponding control and collector electrode lines within each of the other segmented cathode blocks may also be electrically connected to the pulsed control and collector electrode lines, corresponding intersecting cells in each of these other segmented blocks may likewise be pulsed. However, by the simultaneous application of a pulse to only the segmented cathode block containing the cell to be addressed, for example, only the desired cell to be addressed is responsive to be written or erased, with the corresponding cells within each of the remaining blocks being inoperative to change due to the absence of a pulse to the addressing cathode blocks within which they exist.

It is, therefore, an object of the present invention to provide an improved gas discharge display device.

It is a further object of the present invention to provide a d.c. gas discharge display device having bistable switching characteristics, and which is simply addressed.

It is yet a further object of the present invention to provide a low voltage gas discharge display device whereby the drive circuits required therefor are simple and inexpensive.

It is yet still a further object of the present invention to provide an improved low voltage gas discharge display device whereby the number of drive circuits required therefor is reduced.

It is another object of the present invention to provide a low voltage d.c. gas discharge display device which operates in a manner so as to allow simple and lost cost drive circuitry therefor to be employed for the control thereof.

It is yet still another object of the present invention to provide an improved addressing arrangement for gas discharge display devices whereby the number of drive circuits required therefor is made optimally small.

It is yet another object of the present invention to provide a three or more electrode low voltage gas discharge display device whereby an area cathode electrode and/or anode electrode are segmented into blocks such that a selected one of commonly addressed intersecting control and collector electrode lines may be selected by pulsing the appropriate segmented block, whereby the number of drive circuits required for the matrix array of control and collector lines is reduced.

It is yet still another object of the present invention to provide a gas discharge display device fabricated in the form of an array of individual discharge cells, each cell of which may be quiescently biased into a low glow state by low voltage d.c., and which is selectively addressable to be driven into a stable positive column high glow discharge state by low voltage pulses with the number of drive circuits required to produce such pulses being optimally minimum whereby the drive circuitry required to address such device is simple and inexpensive.

In accordance with the principles of the present invention, a display device is formed from an array of discharge cells, with the anode and/or cathode of the device being segmented into blocks electrically isolated from one another such that the anode and cathode of each cell within a block are common with one another. In addition, opaque control electrode lines therefor are common to the cells in rows of the array, with transparent collector electrodes therefor common to the cells in columns of the array. Small holes are placed in the control electrode lines, at locations corresponding to the intersection of the columns and rows of the array. Selected ones of the control and collector electrode lines are commonly connected together.

Each of the segmented blocks of the cathode, as described, are quiescently biased sufficiently negative to strike and maintain a low glow d.c. discharge between the anode and cathode sections in each of the cells. A positive potential somewhat greater than the ionization potential of the gas employed is applied to each of the collector electrode lines, and a negative potential is applied to each of the control electrode lines. Although the collector electrode lines are biased positively, no current flows to them as long as the control electrode lines are biased sufficiently negative such that the space charge limited ion sheath surrounding them act to block the small holes therethrough to the collector electrode lines. However, if the bias on selected control electrode lines is made sufficiently less negative, the ion sheath thereof may contract to a point where it no longer can block the control hole thereof, whereby electrons may penetrate the hole. By biasing selected ones of control electrode lines more positively, and by biasing a selected segmented block of the cathode and/or anode, a sufficient number of electrons may then be preferentially induced to penetrate the holes within said blocks, whereby the gas discharge in the selected cell thereof bistably switches from the low glow discharge between anode and cathode to a high intensity positive column glow discharge between cathode and selected collector electrode line.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments of the invention, as illustrated in the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cross-sectional view of a four electrode gas discharge display device employing three or more level addressing, in accordance with the principles of the present invention. FIG. 1 is taken along section lines 1—1, of the exploded perspective view of FIG. 2.

FIG. 2 shows an exploded perspective view of the preferred gas discharge display arrangement in accordance with the present invention, whereby each of the anode and cathode is shown, for illustrative purposes only, segmented into two blocks in a four level addressing scheme.

FIG. 3 shows an exploded perspective view of the preferred gas discharge display arrangement in accordance with the principles of the present invention, whereby only the cathode is shown segmented into four blocks, for illustrative purposes only, in a preferred three level addressing scheme.

## DETAILED DESCRIPTION OF THE DRAWINGS

In the cross-sectional view of the display deivce shown in FIG. 1, transparent faceplate 1, forming the display surface, is shown facing upwardly. Faceplate 1 may comprise any of a variety of transparent materials. Typically, the faceplate is made of glass. Likewise, the remainder of the outer envelope 3 that contains the plasma of the display device, may typically be fabricated from glass. Sealed within the envelope 3 of the display device, is a plasma 5, as known to those skilled in the art. In this regard, the plasma may comprise any of a variety of well known gases employed for gas discharge display devices. For example, helium or helium with small traces of argon may be employed. However, it is clear that any inert gas may be employed, as for example, neon with a dopant of approximately 1 percent argon. The gas is introduced into the envelope to the desired pressure, consistant with cell dimensions, applied potentials, and the like. Typically, the cells are operated somewhat above the minimum on the Paschen curve.

As shown in the cross-sectional view of FIG. 1, area cathode 7 is segmented into blocks 7A and 7B. Electrical insulating divider 47 acts to electrically isolate 7A from 7B. The purpose of segmenting cathode 7 will be explained more fully hereinafter. As can be seen, cathode segment 7A is common to chambers 9 and 11 and cathode segment 7B is common to chambers 13 and 15, each of which chambers is fabricated in insulating layer or spacer 19 and anode 21. In this regard, the hole openings in insulating layer 19 which act to form a portion of the chamber, may be the same size and in registry with the hole openings in anode 21, or alternatively, may be smaller than, but coextensive with, the hole openings in anode 21, as taught in the above cited copending application.

Typically, cathode 7 may comprise a plate or sheet of metal such as molybdenum. The molybdenum sheet is divided into the desired number of segments, as will be described in more detail hereinafter. The segments are separated from one another as shown by insulating divider 47 which may comprise any of a variety of well known insulating materials, such as a dielectric glass sealant, or $SiO_2$. Alternatively, the segmented blocks of the cathode, as well as the anode shown in FIG. 2, may be separated from one another by a sufficiently large opening or space, such space being sufficiently large such that gas discharge between adjacent segments is avoided. Insulating sheets 19 may be fabricated from a dielectric glass, for example. Anode 21 may be fabricated in the same manner as cathode 7. In this regard, the anode and cathode may be fabricated from a single sheet of molybdenum, for example, or alternatively from a stack of thin sheets of molybdenum, to thereby form a laminate-like structure.

As can be seen in FIG. 1, the chambers 9, 11, 13, and 15 shown therein communicate with cathode 7 via the coextensive holes in insulating layer 19, whereby plasma within the envelope 3 is allowed to exist between cathode 7 and anode 21. As can be seen, terminals 23A–23B and 25 act to allow a potential to be applied between the respective cathode segments and the anode. Typically, anode 21 is grounded while cathode 7 is maintained at a negative potential between 100 and 300 volts, depending upon the mode of operation. The manner by which the leads are shown in FIG. 1 extending from the electrodes out through envelope 3 are illustrative only. Any of a variety of ways may be employed for connecting the various electrodes to external drive circuits.

Control line 27, as shown in the cross-sectional view of FIG. 1, is spaced from anode 21 by insulating spacers 29, 31, 33, 35, and 37. As can be seen in FIG. 2, each of the array of horizontal control lines are arranged to insulatably stand-off from anode 21. The array of holes in each of the control lines are arranged to allow plasma to communicate from the respective cell chambers in anode 21 to the respective collector lines 49, 51, 53, and 55. This is represented in FIG. 1 by holes 39, 41, 43, and 45 which allow plasma to communicate from the respective cell chambers in anode 21 to the respective collector lines 49, 51, 53, and 55. In this regard, it can be seen that the collector electrode lines are positioned in slots in insulating spacer 38. The collector electrode lines, which are generally orthogonal to the control electrode lines, are fabricated from a transparent conductive material, such as a thin metal oxide layer, like InO or SnO. Insulating spacer 38 may be fabricated from any of a variety of insulating materials, such as a dielectric glass. The horizontal control lines may be fabricated from any of a variety of conductive materials which are opaque to the low glow discharge state (stand-by state) which prevails in the background in response to the quiescent voltage being applied between the cathode segments and anode 21. Typically, the horizontal control lines may be fabricated from molybdenum or tungsten.

With reference to FIG. 2, there is shown an exploded perspective view of a four level address scheme, in accordance with the principles of the present invention. As can be seen, cathode 7 is segmented into blocks 7A and 7B which are insulated from one another by insulating divider 47. Likewise, anode 21 is segmented into blocks 21A and 21B which are insulated from one another by insulating divider 57. The dashed line designated 21C outlines 4 cells which are selected when a pulse (or no pulse) is applied to terminals 23B and 25B. Further cell selection within these 4 cells is achieved by proper selectionn of the appropriate intersecting horizontal control electrode line and vertical collector electrode line. Thus, if cell 21D were to be addressed, terminals 17B and 59B would be appropriately pulsed. It can be seen, that by segmenting the cathode and anode, the number of control electrode line and collector electrode line drive circuits is thereby reduced. Thus, for example, a drive circuit at 17A may be employed to drive line 27 and 61. Likewise, a drive circuit at 59B may be employed to drive collector lines 51 and 55.

It should be understood, that although the figures show a 4 × 4 cell array, that such is merely for illustrative purposes only, and that any size array may be employed, depending upon individual design choice. In this regard, the array need not be square, and as a matter of fact, a rectangular array may be preferred. It should be noted that in the illustrative 4 × 4 cell array, given as an example in the drawings, that the number of drivers required therefor is the same as where the cathode and anode are not segmented, but rather addressing is achieved by individually driving each of the control and collector electrode lines in a two level half-select mode. Thus, the benefits achieved in reducing the number of drivers by segmenting the cathode and/or anode, is not obtained unless an array larger than 4 × 4 is employed.

With reference to FIG. 3, there is shown a partially exploded perspective view of a three level addressing scheme, in accordance with the principles of the present invention. As can be seen, in the three level addressing scheme, only the cathode is segmented into blocks. Thus, cathode 7 is segmented into blocks 7A, 7B, 7C and 7D, with the various blocks being insulated from one another by insulating dividers 47 and 63. Although not shown in FIG. 3, the remainder of the display device is identical to that shown in FIG. 2. Thus, pairs of horizontal control lines would be commonly connected as shown in FIG. 2. Likewise, pairs of vertical collector lines would be commonly connected as shown in FIG. 2.

It can be seen that, in the three level addressing scheme of FIG. 3, the same number of drive circuits are required to address any cell as is required in the four level approach. This is true regardless of the size or shape of the cell array. However, the three level addressing scheme of FIG 3 is somewhat simpler and more effective than the four level scheme of FIG. 2, and to that extent is preferred.

It should be noted that the array of discharged cells have been arranged in a manner so that the various cells operate independently of one another. This independence can be achieved, to large extent, by placing the anode 21 relatively close to the device cathode 7. A typical 54 × 280 array may, for example, comprise a center-to-center spacing for the various cells of the array of 0.25 cm. The dimensions of the individual cells may typically comprise an anode diameter and thickness of 0.150 cm, and a control electrode hole or opening of 0.060 cm diameter. It should be recognized that the diameter of the holes in insulating layer 19 may be smaller than the anode diameter, so as to thereby assist in obscuring the low voltage glow discharge which is

continuously present in the background. Typically, the control lines may be deposited to a thickness of 0.0125 cm on a glass spacer of 0.025 cm. Finally, the spacing between the anode and cathode may be of the order of 0.015 cm. It should be appreciated that these values are merely exemplary, in that such dimensions are not critical or limiting, and that any of a variety of dimensions and arrangements may likewise, as readily be employed.

Although any of a variety of gases may be employed, helium or helium with argon have been found to be particularly effective. In general, with the anode grounded, d.c. cathode voltages ranging from −150 volts to −200 volts have been found effective to bias the cathode so that the discharge between anode and cathode runs slightly in the abnormal glow region. Pure helium may be introduced into envelope **3** of the display device to a typical pressure of approximately 90 Torr. On the other hand, helium with 0.2 percent argon, for example, may be introduced to a lower pressure of approximately 70 Torr.

The various control electrode lines may be normally biased slightly negative, while the various collector electrode lines may normally be biased to a positive level somewhat in excess of the ionization potential. For example, the respective control electrode lines may be biased, as hereinabove indicated with respect to FIG. **1**, to a potential within the range of from approximately −5 volts to −15 volts. Typically, the collector electrode lines are biased to approximately +50 volts, with the control electrode lines biased to approximately −10 volts.

Accordingly, with reference to FIG. **1**, even though the collector electrode lines **49, 51, 53** and **55** are normally biased positively, no current flows to these lines so long as the control electrode line **27**, for example, is biased sufficiently negative so that the space charge limited ion sheath surrounding this control line blocks the holes **39, 41,** and **43** and **45** therein. Under such conditions, only a small amount of tthe light generated in the background by cells **9, 11, 13** and **15** is visible at faceplate **1**. If, now, the normal control bias on control electrode line **27** is temporarily made less negative, the ion sheath contracts. If the ion sheath contracts sufficiently so that it no longer effectively blocks the control holes, electrons will penetrate these holes and, if enough electrons are allowed to penetrate a selected hole, the cell switches to a different stable state. The current flow to the collector thereof causes additional ionization which lowers the impedance between the collector electrode and negative glow, and more current then flows. When the entire discharge current flows to the collector electrode of the written cell, a second stable state has been reached.

In the second stable state, an intense glow forms where current passes through the small control hole to form positive column glow discharge. Since the collector electrode lines are transparent, an intense glow is readily visible at the viewing surface of the display device, as described in the above cited copending application.

Four Level Address

With reference to the four level addressing scheme, as illustrated by the arrangement of FIG. **2**, two exemplary modes of operation will be described. As hereinabove described, both the cathode and anode are segmented whereby each segment may be selectively addressed. Typically, as hereinabove suggested, each of the collector lines **49–55** may be normally, i.e., quiescently, biased to approximately +50 volts via terminals **59A** and **59B**. Each of the control electrode lines may be normally, i.e., queiscently, biased to approximately −10 volts via terminals **17A** and **17B**. Cathode segmented blocks **7A** and **7B** may each be quiescently biased to approximately −150 volts. Segmented blocks **21A** and **21B** of anode **21** may each be quiescently biased to approximately ground potential. In accordance with such quiescent bias conditions, a low glow discharge exists in each of the cells between cathode **7** and anode **21.**

In order to write in a given cell to effect a positive column glow discharge therein, four pulses are required. For example, in order to write in cell **21D**, a positive pulse of approximately 10 volts may be applied to terminal **17B** to reduce the ion sheath in the control electrode holes associated therewith, as hereinabove described. Simultaneous with the application of a positive 10 volt pulse to terminal **17B**, another 10 volt positive pulse, for example, is applied to terminal **59B**. Such pulses may be, for example, of 1.5 μs duration. Thus, it can be seen that partial-select pulses are applied to the respective control and collector electrode lines connected to terminal **17B** and **59B**, respectively. Under such conditions, where no further selection is effected, each of the cells corresponding to addressed intersecting control and collector electrode lines would be written. In order to further reduce the selection, so that only cell **21d** is written, anode block or segment **21A** is pulsed positively simultaneously with the application of positive pulses to terminal **17B** and **59B**. Segment **21A** may be pulsed to approximately +10 volts with a 1.5 μs pulse, for example. In this regard, then, it should be noted that in taking the general case where there are N anode segments, that all of the segments other than the segment in which the cell to be written exists, are pulsed positively. To effect a further reduction in the selection process, cathode segment **7B** is pulsed negatively simultaneously with the application of the three foregoing described pulses. Typically, segment **7B** would be pulsed to approximately −10 volts with a 1.5 μs pulse, for example. In the same manner as above, then, in taking the general case where there are N cathode segments, only the cathode segment containing the cell to be written is pulsed negatively while the other segments remain at their quiescent bias level.

It should be understood that the foregoing described pulsing technique is merely exemplary of one manner by which the arrangement shown in FIG. **2** may be biased and pulsed to write or erase a given cell. In this regard, the quiescent bias and pulse values given are relative, and other conditions and relationships may as readily be employed to produce the same type of operation. For example, a 20 volt quiescent bias could readily be applied to the control electrode lines, and rather than positively pulse the anode segments which do not contain the cell to be written, a negative 10 volt pulse could be applied to the anode segment containing the cell to be written. Under such conditions, with the 20 volt quiescent bias on the control electrode lines being reduced to a −10 volts by the 10 volt pulse applied thereto, the same overall relationship between the anode and control electrode lines as achieved in the previous example, is thereby achieved. In this regard,

the net effect of selectively pulsing the cathode and anode segments is to cause a temporary control bias shift whereby a positive column glow discharge is effected between cathode 7 and the collector electrode lines only within the selected cathode and anode segments. It can be seen, that where a positive column glow discharge is effected in a given cell, the collector electrode line therefor then acts as the new anode.

It has been found that best results are achieved by having the pulses applied to the cathode and anode segments lead the partial-select pulses applied to the control and collector electrode lines by approximately 100 μs. Although not critical, this lead time allows the conditions within each cell to reach an equilibrium condition before the control and collector electrode lines are pulsed simultaneously with the partial-select pulses. Thus, where the control and collector electrode line pulses are of a duration of approximately 1.5 μs, cathode and anode segment pulses of approximately 100 μs applied approximately 98 μs before the 1.5 μs pulses, would be sufficient for this purpose.

Three Level Address

With reference to the three level address scheme of FIG. 3, two exemplary modes of operation will be described. Typically, the collector electrode lines as shown in FIG. 2 may be quiescently biased to +50 volts and the control electrode lines quiescently biased to −10 volts. Each of cathode segments 7A, 7B, 7C and 7D may be quiescently biased to −150 volts. Anode 21, which is unsegmented, may be quiescently held at ground potential.

In order to write cell 21D, as hereinabove described with regard to the four level address, partial-select positive 10 volt pulses may be applied to terminals 17B and 59B. In this mode of operation, the 10 volt partial-select pulses is applied to 17B and 59B are made of sufficiently short durations so that the ion sheath around the control lines is not sufficiently reduced to thereby allow establishment of positive column glow discharge. In order to write cell 21D, a negative pulse of from approximately 10 to 15 volts, for example, is applied to cathode segment 7C. The net effect of applying such a negative pulse to cathode segment 7C is to cause the cathode to induce a higher current in cell 21D. In this regard, the speed at which switching to positive column glow discharge is effected is a function of the magnitude of the current in the cell. Thus, with higher current in cell 21D, the short partial-select 10 volt pulses applied to 17B and 59B are sufficient to effectively reduce ion sheath and cause positive column glow discharge to be produced in cell 21D. Typically, the 10 volt partial-select pulses applied to terminal 17B and 59B for this purpose, may be of the order of 0.5 μs although this is not critical and varies with other parameters.

It is clear that any of a variety of schemes may be employed in the three level addressing arrangement, whereby higher currents may be selectively induced in the cells which are within the particular cathode segment which is driven from its normal −150 volt level to, for example, a −165 volt level. For example, it is clear that all the cathode segments could be biased to a negative 165 volts. Under such conditions, when addressing a given cell, all cathode segments not of interest may be positively pulsed by a 15 volt, 100 μs pulse. It can be seen, that such would have substantially the same effect as pulsing the cathode segment of interest negatively, as above described. As is the case with the four level address scheme, best results are obtained by applying the cathode pulses approximately 100 μs before the control and collector electrode lines aree pulsed.

Optimizing the Number of Drivers

As hereinabove mentioned, segmenting the cathode and anode in a 4 × 4 cell array as shown in the drawings, does not act to provide any benefit in terms of reducing the number of drivers but merely acts to illustrate the manner by which three level and four level address schemes operate in a low voltage gas panel arrangement, in accordance with the principles of the present invention. As will be shown hereinafter, in a relatively large array of cells, substantial reductions in the number of drive circuits may be achieved by judicious segmentation of the cathode in both the three level and four level addressing scheme, in accordance with the principles of the present invention. To simply illustrate this point for a three level addressing arrangement, an 8 × 8 cell array may be taken by way of example. In two level half-select addressing of an 8 × 8 cell array, wherein there is no segmenting of the cathode or anode and each control electrode and collector electrode line is individually driven, the number of drive circuits $N_d$ is given by $N_d = N_x + N_y$. $N_x$ is the number of drive circuits in the X direction and $N_y$ is the number of drive circuits in the Y direction. Thus, $N_d = 16$ in an 8 × 8 array with two level addressing.

However, where the cathode is segmented in accordance with the principles of the present invention to thereby allow three level addressing, $N_d$ is significantly less. In an 8 × 8 array, segmenting the cathode into quarters as shown in FIG. 3, for example, results in 16 cells being apportioned to each segmented block. By commonly connecting the corresponding control electrode lines and collector electrode lines within each segmented block, it can be seen that four drive circuits are required for the control electrode lines and four drive circuits are required for the collector electrode lines. Thus, $N_d$ for three level addressing of the 8 × 8 cell array is 12 (viz. drive circuits for four segmented blocks plus four drive circuits for the control electrode lines and four drive circuits for the collector electrode lines).

As is evident, there are many ways in which the area cathode for a given array of cells may be broken up into segments. In this regard, the segments do not have to be square, and segmenting to obtain an optimally minimal number of drive circuits may at times require the segments to be rectangular. Likewise, the cathode segments do not have to be equal to one another, but simplicity, convenience of fabrication, and relative ease in attaining a practical minimum number of drive circuits suggest that the better approach is to divide the cathode into equal or substantially equal segments. With equal or substantially equal segments, each segment contains the same number of cells where the array of cells are uniformly displaced. It is possible, however, to have a lesser number of cells within certain segments, if desirable. However, in most practical applications it is preferred that the cells be uniformly displaced with each segment having the same number of cells.

It can be shown that the minimum number of drive circuits $N_d'$ for a three level address scheme is given by

$$N_d' = 3(N_x N_y)^{1/3}$$

under the conditions that

$N_{zx} = (N_x^2/N_y)^{1/3}$ and $N_{zy} = (N_y^2/N_x)^{1/3}$

where $N_{zx}$ is the number of cathode segments or drive circuits in the X direction and $N_{zy}$ is the number of cathode segments or drive circuits in the Y direction.

It should be recognized that the above stated $N_d'$ expression is obtained by minimization techniques and consequently contemplates results which may be less than integers. In practice, however, it is clear that where the value of $N_d'$ turns out to include fractional portions of a segment or drive circuit, it is rounded out to integer values of $N_d'$. Thus, the ideal minimum may not always be reached. Likewise, $N_{zx}$ and $N_{zy}$ are rounded out to integer values.

To demonstrate the manner by which the judicious segmenting of the cathode to provide three level aaddressing may, in accordance with the principles of the present invention, operate to permit use of an optimally minimum number of drive circuits, the following example is given. Consider a 40 character × 6 character display. Taking a 7 × 9 cell matrix for each character (including spacing between characters), then, $N_x = 280$ and $N_y = 54$.

With ideal division of the segments,

$N_{zx} = (N_x^2/N_y)^{1/3} = 11.3$

$N_{zy} = (N_y^2/N_x)^{1/3} = 2.18$ and

$N_x' = N_y' = (N_xN_y)^{1/3} = 24.75$

where $N_x'$ is the number of X drive circuits, i.e., collector electrode line drive circuits, and $N_y'$ is the number of Y drive circuits, i.e., control electrode line drive circuits. For the X direction, i.e., collector electrode lines, two choices are reasonable. $N_{zx}$ may be taken as 10 or 14 which means that cathode 7 may be divided into either 10 or 14 segments in the X direction. With 10 cathode segments in the X direction, $N_x'$ would be 28 which means that each cathode segment in the X direction would encompass 28 collector electrode lines. Respective ones of the 28 collector electrode lines of each segment may then be electrically connected together, whereby only 28 drive circuits are required for the X direction. In this regard, the first collector electrode line of each segment may be connected to the first collector electrode line of every other segment, etc.

In the above example $N_{zy} = 2$ is practically optimum. Thus, cathode 7 in this example may be divided into two segments in the Y direction. With two cathode segments in the Y direction, $N_y'$ would be 27 which means that each cathode segment in the Y direction would encompass 27 control electrode lines. Thus 27 drive circuits are required in the Y direction. It can be seen that each cathode segment requires a 28 × 27 cell array, and thus is nearly square in this example.

Whether $N_{zx}$ is taken as 10 or 14 ($N_x' = 28$ or 20) in the above example, the $N_d'$ expression given to define the optimally minimum total number of drivers turns out to be 75. This figure is obtained in the case of $N_{zx}$, for example, by summing the 28 drive circuits required for the collector electrode lines, the 27 drive circuits required for the control electrode lines and the 20 drive circuits required for the cathode segments.

The 75 drive circuits required in the above example of the three level addressing, in accordance with the principles of the present invention, compares with 334 (280 + 54) drive circuits required where conventional two level addressing is employed.

Where both the cathode and anode are segmented to provide four level addressing in accordance with the principles of the present invention, it can be shown that the optimally minimum number of drive circuits is given by

$$N_d' = 2\sqrt{N_x} + 2\sqrt{N_y},$$

and that

$$N_{zx} = \sqrt{N_x} \text{ and } N_{zy} = \sqrt{N_y}.$$

The following table is provided by way of example to demonstrate the comparative number of drive circuits required for two level, three level and four level addressing in a 280 × 54 cell array and a 400 × 400 cell array. These results were obtained in a manner analogous to the manner employed in the above described example.

| Level of Addressing | Minimum No. of Drive Circuits — Display Format ($N_x$ . $N_y$) | |
|---|---|---|
| | 280 × 54 | 400 × 400 |
| Two Level Addressing | 334 drive circuits | 800 drive circuits |
| Three Level Addressing | 75 drive circuits | 164 drive circuits |
| Four Level Addressing | 49 drive circuits | 80 drive circuits |

Although no specific example has thus far been described with reference to segmenting only the anode as an alternative approach to three level addressing, it should be understood that the anode may be segmented in the same manner as the cathode, in accordance with the principles of the present invention. However, somewhat of a disadvantage resides in segmenting the anode as opposed to the cathode to achieve three level addressing, in the relative ease with which leads may be brought to the exterior of glass envelope **3** from each segment is not the same. Since cathode **7** is adjacent the envelope, leads may readily be brought out to drive circuits, and for this reason segmenting the cathode is preferred.

It should be appreciated that although certain of the control and collector electrode lines are shown being electrically connected together external to envelope **3**, in practice such connections may be made internal to envelope **3**. For example, although control electrode lines **27** and **61** in FIG. **2** are shown connected externally by lead **65**, it is clear that lead **65** may instead be a conductive line which is deposed upon insulating layer **38**. In this regard, it is clear that where several control electrode or collector electrode lines are to be electrically connected together, these connections may be made alternately from the end of one line to the next.

It should be recognized that with the display device of the present invention, various other advantageous modes of operation are readily possible. For example, when the positive column is turned on, the positive shift in plasma potential increases the potential difference between plasma and cathode. The cathode voltage can then be reduced so as to turn off the sustaining discharge of the unused cells without extinguishing those cels which have been written, i.e., have the positive column ignited. This improves the contrast ratio and decreases the power dissipation of the display. Further, once the sustaining discharge of the unused cells has been extinguished, power dissipation of those cells still

ignited (i.e., written) can further be reduced by sustaining those discharges with pulses to the cathode rather than a constant d.c. voltage. The reduction in light output when operated in this mode can be compensated by coating the second anode with an efficient low energy cathodoluminescent phosphor, such as ZnO.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a gas discharge display device including an N × M array of cells therein having at least one cathode area electrode means common to both rows and columns of cells of said array of cells and having N area electrode means respectively common to the N rows of cells of said array of cells for addressing rows of cells and having M area electrode means respectively common to the M columns of cells of said array of cells for addressing columns of cells, the improvement comprising:

the said at least one cathode area electrode means including at least two electrode segment means arranged so that each of said electrode segment means is common to more than one cell within said electrode segment means with each of said electrode segment means being electrically insulated from one another and separately addressable with the number $N_z$ of said at least two electrode segment means being the product of the numbers $N_{zx}$ and $N_{zy}$ given approximately by the relationships

$$N_{zx} = (N_x^2/N_y)^{1/3}$$
$$N_{zy} = (N_y^2/N_x)^{1/3}$$

where $N_{zx}$ is the number of electrode segment means in the X direction, $N_{zy}$ is the number of electrode segment means in the Y direction and $N_x$ and $N_y$ are the respective numbers of columns and rows of cells in said $N \times M$ array of cells; and

corresponding ones of said N area electrode means within respective ones of the said at least two electrode segment means being electrically coupled to one another so as to form $N_x'$ address terminals in the X direction and corresponding ones of said M area electrode means within respective ones of the said at least two electrode segment means being electrically coupled to one another so as to form $N_y'$ address terminals in the Y direction such that $N_x + N_y$ is less than N + M, whereby at least three level addressing of the cells of said array of cells is provided to thereby reduce the number of drive circuits required therefor.

2. The device as set forth in claim 1 wherein the value of $N_x'$ is equal or approximately equal to $N_x$ divided by $N_{zx}$ and wherein the value of $N_y'$ is equal or approximately equal to $N_y$ divided by $N_{zy}$.

3. The device as set forth in claim 2 wherein the said cathode electrode means comprises $N_z$ segments for three level addressing of the said N × M array of cells whereby the total number of drive circuits required therefor is the sum of $N_z + N_x' + N_y'$.

4. In a low voltage gas discharge display device having an array of cells with each cell having anode and cathode electrode means for quiescently establishing a low glow background discharge in each cell, with said low glow background discharge being switchable to a positive column glow discharge between said cathode electrode means and collector electrode means in response to application of select pulses to both said collector electrode means and a control electrode means interposed between said collector electrode means and said anode electrode means, the improvement comprising;

segmenting at least one of said anode and cathode electrode means into at least two electrode segments so that each of said electrode segments is common to more than one cell within said segment and electrically insulated from one another, with each of said electrode segments being separately selectively addressable with the number $N_z$ of said segments being the product of the numbers $N_{zx}$ and $N_{zy}$ given approximately by the relationships

$$N_{zx} = (N_x^2/N_y)^{1/3}$$
$$N_{zy} = (N_y^2/N_x)^{1/3}$$

where $N_{zx}$ is the number of electrode segments in the X direction, $N_{zy}$ is the number of electrode segments in the Y direction and $N_x$ and $N_y$ are the respective numbers of columns and rows of cells in said array of cells; and

arranging said collector electrode means including collector electrode lines so that respective ones of said collector electrode lines are arranged along the respective columns of cells of said array of cells with corresponding collector electrode lines within each of the respective segments being electrically coupled to one another so as to form $N_y'$ address terminals in the Y direction and arranging said control electrode means including control electrode lines so that respective ones of said control electrode lines are arranged along the respective rows of cells of said array of cells with corresponding control electrode lines within each of the respective segments being electrically coupled to one another so as to form $N_x'$ address terminals in the X direction.

5. The device as set forth in claim 4 wherein the value of $N_y'$ is at least approximately equal to $N_y$ divided by $N_{zy}$ and wherein the value of $N_x'$ is at least approximately equal to $N_x$ divided by $N_{zx}$.

6. The device as set forth in claim 5 wherein the said cathode electrode means is segmented into said number $N_z$ of said at least two electrode segments for three level addressing whereby the number of drive circuits required therefor is the sum of the numbers $N_z + N_y' + N_x'$.

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