

[54] **VISUAL DISPLAY DEVICES**

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[22] Filed: **June 19, 1973**

[21] Appl. No.: **371,355**

[52] U.S. Cl. **315/169 TV**; 313/201; 313/217; 313/220

[51] Int. Cl. **H01j 11/02**; H01j 65/04

[58] Field of Search..... 313/217, 220, 201; 315/169 R, 169 TV

[56] **References Cited**

UNITED STATES PATENTS

3,509,408	4/1970	Holz.....	313/201
3,636,405	1/1972	Cotter.....	313/220 X
3,681,655	8/1972	Toombs.....	315/169 R
3,764,847	10/1973	Smith.....	313/220 X
3,771,008	11/1973	Chen et al.	313/217 X
3,789,265	1/1974	Holz et al.	315/169 TV
3,790,849	2/1974	Mayer et al.	315/169 TV

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[57] **ABSTRACT**

A visual display device consists of a matrix of cold-cathode direct-current discharge devices any one of which is addressable by a cross-bar arrangement of conductors to produce a required display. Each discharge device is provided with a subsidiary electrode, say an anode, spaced further than the main anode electrode from the cathode electrode. The subsidiary electrodes are capacitively coupled to conductors grouped as for the main anodes. The arrangements permit discharge devices which contained a discharge and which have been turned off to be turned on a short time later by way of a pulse applied to the subsidiary anodes but not those devices which did not contain a discharge. By varying the time delay between turn-off and turn-on, variable brightness can be obtained.

10 Claims, 4 Drawing Figures

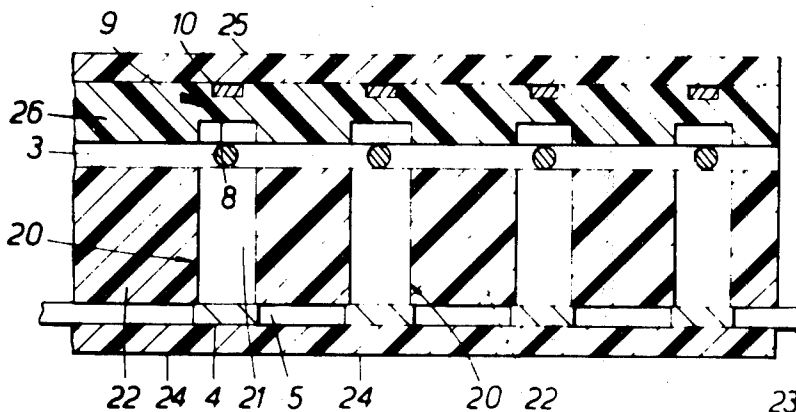


FIG. 1.

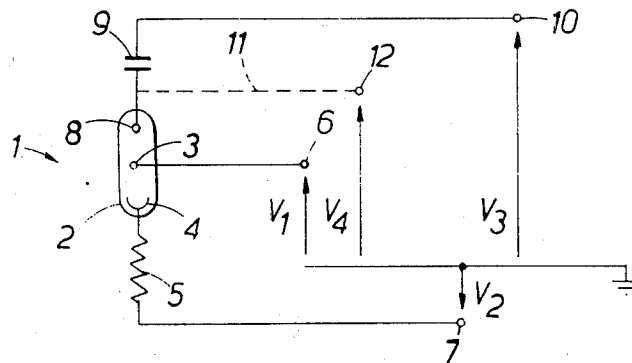


FIG. 2.

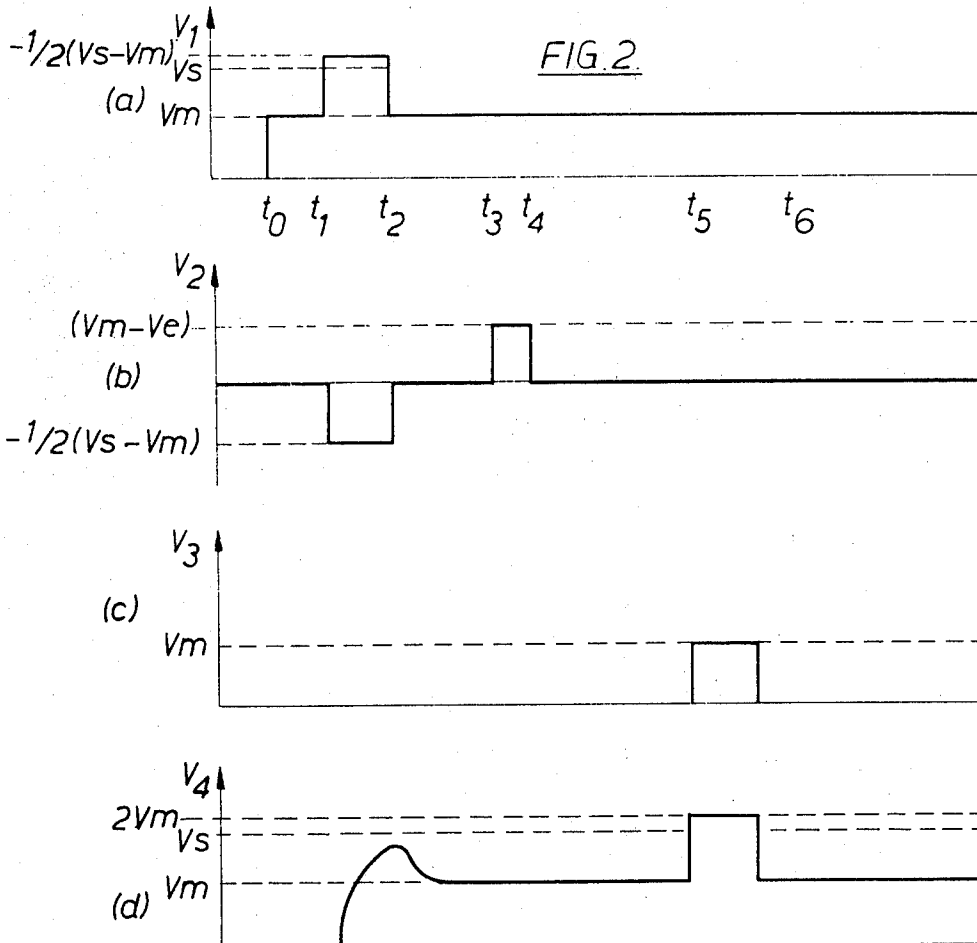


FIG. 3.

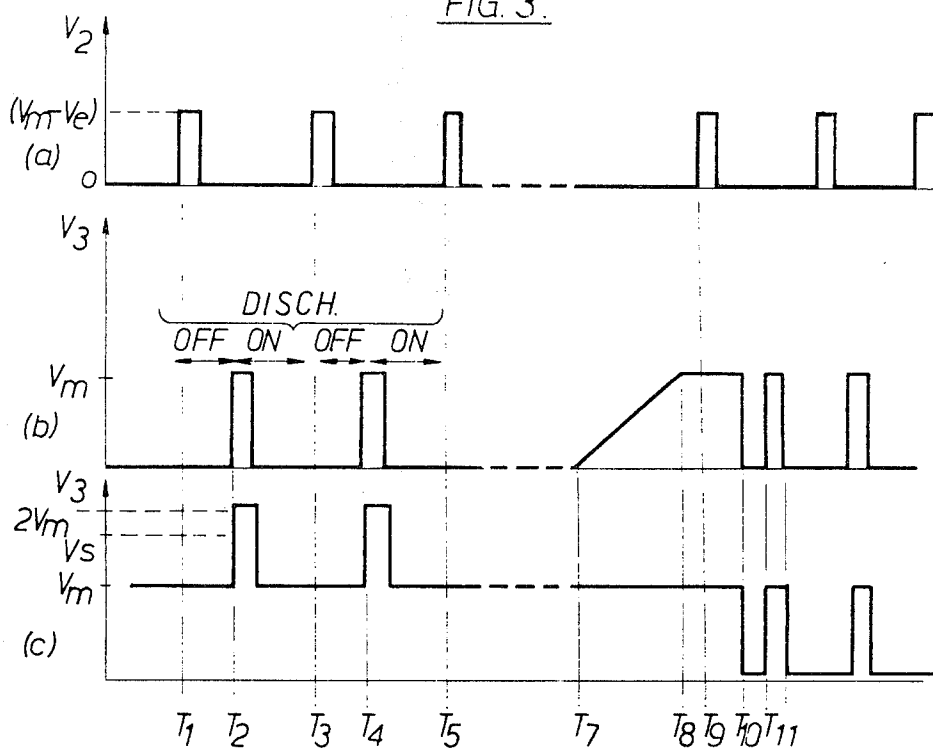
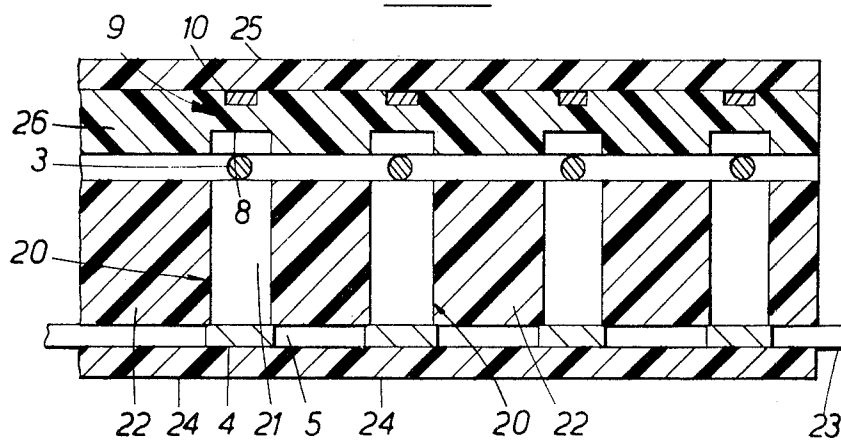


FIG. 4.



VISUAL DISPLAY DEVICES

This invention relates to visual display devices and in particular to such devices incorporating an array of gas-filled cold-cathode direct-current discharge devices each of which may be struck or extinguished to produce a display of the required form.

Visual display devices are known which incorporate an array of direct-current discharge devices formed from one or more gas-filled apertures in a block of electrically insulating material such as glass or ceramic. Each discharge device is provided with an electrode and series impedance, either integral with, or outside the device.

Such devices are versatile in that many types of information characters may be displayed simultaneously. However, because of the nature of the discharge, they are limited in the variations obtainable in the light output and, therefore, in the observed brightness. The light output is dependent upon factors such as the composition of the discharge gas, the pressure of the gas, the separation of the electrodes and the applied voltage. The first three factors are fixed during manufacture and the latter is variable only between the limits at which a discharge is struck and at which a discharge is extinguished. The light output at the extinguishing level of the voltage may be typically half of that of the striking level of the voltage, thereby giving a light output ratio of only 2 to 1.

It is an object of the present invention to provide a visual display device incorporating an array of gas-filled cold-cathode direct-current discharge devices in which the light output part or all of the display device may be varied over a wider range than heretofore possible.

According to the present invention a visual display device incorporates a two co-ordinate array of gas-filled cold-cathode direct-current discharge devices, each discharge device of the array having a gas filled discharge space, a first electrode communicating with the discharge space, an impedance element connected to the first electrode, a second electrode in communication with the discharge space, a third electrode in communication with the discharge space and more remote than the second electrode from the first electrode, and a capacitance element connected to the third electrode, the array also comprising a first set of electrical conductors individual conductors of the set interconnecting the impedance elements of the discharge devices associated with individual values of one co-ordinate of the array, a second set of electrical conductors individual conductors of the set interconnecting the second electrodes of the discharge devices associated with individual values of the other co-ordinate of the array, and a third set of conductors individual conductors of the set interconnecting the capacitance elements of the discharge devices associated with individual values of said other co-ordinate of the array.

A visual display device as described in the preceding paragraph may comprise a block of electrically insulating material containing a two-co-ordinate array of gas-filled apertures, each aperture forming a discharge space of an individual discharge device, a first end-plate of electrically insulating material sealing one end of the apertures and carrying on a face adjacent the apertures the first electrodes, the impedance elements and the first set of electrical conductors, a second end

plate of electrically insulating material retaining the second electrodes adjacent the other end of the apertures and sealing the other end of the apertures.

The third set of electrical conductors may be deposited on the second end-plate so that individual conductors extend parallel to corresponding conductors of the second set of conductors and the series capacitance elements may be formed by a layer of transparent dielectric material covering the second end-plate and the third set of electrical conductors.

The third electrodes may comprise parts of the dielectric layer of reduced thickness in registration with the apertures. The dielectric material may be a solder glass having a suitable coefficient of expansion for direct deposition on the end-plate.

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

FIG. 1 is schematic circuit representation of a single discharge device having a variable light output,

FIG. 2 shows waveforms of the variation with time of voltages across parts of the circuit of FIG. 1 to produce restriking of a discharge,

FIG. 3 shows waveforms of the variation with time of voltages across parts of the circuit of FIG. 1 to produce variations in the overall light output, and

FIG. 4 is a sectional elevation through a visual display device comprising an array of individual discharge devices.

Referring now to FIG. 1, there is shown a circuit representation of a discharge device 1. The device comprises a sealed glass envelope 2 containing a suitable gas, such as neon, at low pressure. The envelope also contains a main anode electrode 3 and a cathode electrode 4, both extending through the wall of the envelope. A series impedance element in the form of a current limiting resistor 5 is placed in the cathode lead. The main anode 3 is connected to a terminal 6 and the resistor 5 is connected to a terminal 7. This part of the device is conventional in that a potential difference of the correct magnitude applied between terminal 6 and terminal 7 will cause a discharge to strike between the two electrodes. This may be applied as a positive potential V_1 to terminal 6 and a negative potential V_2 to terminal 7. The envelope also contains a subsidiary anode 8 spaced further away from the cathode 4 than the anode 3. The subsidiary anode is connected externally, by way of a capacitor 9, to terminal 10.

Although no physical connection is made to the subsidiary anode, a connection is shown in FIG. 1 by the broken line 11 and terminal 12, and this connection may be used to describe the operation of the device with reference also to FIG. 2. FIG. 2(a) shows the waveform of the voltage, V_1 , between terminal 6 and ground, FIG. 2(b) shows the waveform of the voltage, V_2 , between terminal 7 and ground, FIG. 2(c) shows the waveform of the voltage, V_3 , between terminal 10 and ground, and FIG. 2(d) shows the waveform of the voltage, V_4 , between terminal 12 and ground.

Initially at time t_0 when there is no discharge in the device the terminals 7 and 10 are connected to ground, that is $V_2 = 0$ and $V_3 = 0$, and the terminal 6 is at discharge maintaining potential $V_1 = V_m$, with respect to ground. To strike a discharge, the potential V_1 is increased by the addition of a pulse of value greater than $\frac{1}{2}(V_s - V_m)$, where V_s is the discharge striking voltage, and the potential V_2 is reduced to a value $-\frac{1}{2}(V_s$

$-Vm$), both at time t_1 . The potential difference between the main anode 3 and the cathode 4 is thus greater than V_s and a discharge is caused to strike. When the discharge has formed properly at time t_2 , the pulses $\pm \frac{1}{2} (V_s - V_m)$ are removed and the discharge is maintained by the maintaining voltage V_m between the main anode 3 and the grounded cathode 4.

As soon as the gas is ionized at the start of the discharge the subsidiary anode 8 collects a positive charge from its nearest neighbor, the main anode 3, and the capacitor charges. At the time t_2 , when V_1 falls to V_m , the charge on the capacitor 9 decays and V_4 also falls to a value approximately equal to V_m . If at some later time t_3 the potential V_2 of the cathode 4 is increased to $(V_m - V_e)$, where V_e is the voltage which is just insufficient to maintain a discharge, then the potential difference between the anode and cathode is less than V_e and the discharge is extinguished. The discharge is not re-struck when V_2 returns to zero. The capacitor 9 retains its charge and the voltage V_4 remains virtually constant. Charge will, of course, tend to leak from the capacitor and for one having a value of say 100 pf such a discharge would take minutes or hours to complete.

At a later time t_5 the terminal 10 is disconnected from ground and a voltage pulse V_3 is applied having a potential V_m . The sudden increase of voltage on one side of the capacitor is transmitted as an identical increase of the voltage at the other side and consequently at the subsidiary anode. The voltage V_4 is thus increased to approximately $2V_m$, but greater than V_s , for the duration of the pulse and causes a discharge to form between the subsidiary anode 8 and the cathode 4. The pulse continues until time t_6 and is equal in duration to the pulse required to strike the initial discharge at time t_1 . At the end of the pulse, the terminal 10 is reconnected to earth, but the discharge is maintained between the main anode and the cathode. The voltage V_4 is returned to its previous value of approximately V_m . Thus once a discharge has been struck by applying a striking pulse to the main anode 3, the discharge can be extinguished and restriking without the potential applied to terminal 6 and terminal 10 exceeding V_m .

The re-striking capability introduced by the capacitor 9 enables the overall light output of the device to be varied. Referring to FIG. 3 the voltage between the main anode 3 and ground is $V_1 = V_m$ and it is assumed that a discharge is being maintained in the device. The voltage V_2 between the cathode and ground is shown in FIG. 3(a). This voltage is increased to $(V_m - V_e)$ by a train of pulses of 50 microseconds duration at 20 milliseconds intervals, that is at 50 Hz repetition frequency at times $T_1, T_3, T_5, \dots$. The voltage V_3 applied to terminal 10 is shown in FIG. 3(b) as a train of pulses of value V_m each occurring at some time between the pulses of V_1 at times $T_2, T_4, \dots$. It will be appreciated from the explanation given above that the discharge is extinguished following each pulse of V_2 and is restriking at each pulse of V_3 so that the average light output forming the subjective brightness is dependent on the on/off time ratio of the discharge, that is, $T_3 - T_2$ to $T_3 - T_1$. This ratio may be varied by altering the delay between a pulse of V_3 following a pulse of V_2 . Maximum brightness is obtained by applying the restriking pulse of V_3 immediately following the extinguishing pulse of V_2 and minimum brightness is obtained by applying the restriking pulse of V_3 immediately prior to the next extinguishing pulse of V_2 .

The striking of a discharge takes place at some 30 microseconds into the striking pulse, which may have to be of 200 microseconds duration in order to establishing the discharge sufficiently for it to be maintained by the lower maintaining voltage. Thus where a striking pulse immediately follows an extinguishing pulse there is an unavoidable period of 30 microseconds when no discharge is struck, but this is so short with respect to the 20 millisecond period that the brightness is virtually identical with that produced by a continuous discharge. If the restriking pulse is struck immediately before the next extinguishing pulse so as to produce minimum brightness, then the pulse has to be applied 200 microseconds before the extinguishing pulse so as not to overlap it. Therefore, the discharge is struck for about 170 microseconds, that is, from 30 microseconds into the pulse before it is extinguished. The on/off time ratio is therefore 0.17 to 20, that is, almost 1 to 100. Using pulses of constant duration a maximum contrast ratio of 100 to 1 is obtainable. This may be increased by employing restrike pulses of variable duration, when a pulse of duration slightly greater than 30 microseconds applied just prior to the next extinguishing pulse would provide an almost infinite contrast ratio.

The removal of the automatic restriking ability so that the application of the pulses of V_2 does not cause restriking may be described with reference to FIG. 3 parts (a), (b) and (c). During a period when the discharge is struck, say at time T_7 , the voltage V_3 applied to the terminal 10 is increased to V_m . This may be in the form of a slowly rising ramp so that when the capacitor 9 is charged, the voltage across it is zero. When this condition has stabilised at time T_8 the extinguishing pulse is applied to the cathode 4 by way of terminal 7 and the discharge is extinguished, remaining so even when V_2 returns to zero at time T_9 . At some later time T_{10} the voltage V_3 is reduced to zero in a negative going step. The sudden change in potential of the side of the capacitor connected to the terminal 10 is transmitted by the capacitor so that the potential of the subsidiary anode 8 falls by the same amount to give a value to V_4 (FIG. 3(c)) of approximately zero. When a subsequent restriking pulse of value $V_3 = V_m$ is applied to the terminal 10 at time T_{11} the potential of the subsidiary anode 8 rises to approximately V_m and this level is insufficient to cause restriking of the discharge. This continues until V_1 is again increased to a striking level V_s and a discharge in the device again raises the potential of the subsidiary anode to approximately V_m .

A visual display device according to the present invention may be formed by appropriate interconnection of the terminals 6, 7 and 10 of a plurality of the devices 1 arranged in the rows and columns of a rectangular matrix. All the terminals 7 of the devices along a column of the array are interconnected by an individual column conductor of a first set of conductors and all the terminals 6 of the devices extending along a row of the array are interconnected by an individual row conductor of a second set of conductors. All of the terminals 10 of the devices extending along a row of the array are also interconnected by an individual subsidiary row conductor of a third set of conductors. A display employing discrete discharge devices so connected would be suitable for large size displays, for example, advertising hoardings, but on a smaller scale, the device may be constructed as now described with reference to FIG. 4. In the sectional elevation of FIG.

4, the parts corresponding to those shown in FIG. 1 are indicated by like numerals.

A plurality of discharge devices 20 are defined by an array of apertures 21 arranged in the rows and columns of a rectangular matrix in a block 22 of electrically insulating material. At one end of each aperture is a first cathode, electrode 4 and a series impedance element 5, each impedance element 5 of the devices forming one row of the matrix being connected to a common row conductor 23 of a first set of electrical conductors. Conveniently, the cathode 4, impedance element 5 and row conductors 23 are printed and/or otherwise deposited on a first end plate 24, also formed of electrically insulating material. The plate 24 is held in contact with the block 22 with the cathode electrode 4 in registration with the apertures 21. The plate and the block are sealed around their edges to provide a gas-tight closure for the apertures 21.

The anodes or second electrodes of the devices are formed by wire anode conductors 3 of a second set of conductors passing over the other end of the apertures, all of the devices in one column of the matrix being interconnected by a common anode conductor.

A second end plate 25 of transparent electrically insulating material closes the apertures at the anode end. The plate 25 has deposited thereon a set of third or subsidiary anode conductors 10 (corresponding to the terminal 10 of FIG. 1) which are also transparent. The conductors 10 are arranged to lie parallel to the anode conductors 3 and are covered by a layer of transparent dielectric material 26. The dielectric material is reduced in thickness at the points where the layer is in registration with the apertures 21. For each device the part of the dielectric layer of reduced thickness is equivalent to the capacitor 9 of FIG. 1. The subsidiary anode 8 of FIG. 1 does not exist as a physical component, but its action is performed by the inner surface portion 8 of the dielectric layer.

The second end plate is also sealed to the block 22 in a gas-tight seal and the device filled with a suitable neon or neon/tritium gas mixture at the required pressure.

In operation all of the anode conductors are maintained at a potential of $+V_m$ with respect to ground (where V_m is the maintaining voltage) and all of the cathode conductors are maintained at ground potential. To initiate a discharge in any particular discharge device, the potential of the appropriate anode conductor is raised by the addition of a pulse $\frac{1}{2}(V_s - V_m)$ and the potential of the appropriate cathode conductor is lowered by a pulse $-\frac{1}{2}(V_s - V_m)$, to give a potential difference between the anode and cathode of V_s . After sufficient time has elapsed for a discharge to be established, the pulses are removed and the potential difference across the cell returns to V_m , the discharge being maintained. Further discharges may be struck in other devices by similar selection of anode and cathode conductors.

When the desired discharges have been struck to form the display, the potential of all of the cathode conductors is raised from ground potential to $(V_m - V_e)$ in 50 microsecond extinguishing-pulses at a 20 millisecond repetition frequency as described with reference to FIG. 3. The drop in the potential difference between electrodes causes the discharge to be extinguished in all the discharge devices.

At some predetermined time before the next extinguishing pulse a pulse of potential V_m and of the required duration is applied to all of the subsidiary anode conductors 10. The change in potential, transmitted through the dielectric layer to the face 8, is $+V_m$ which is additive with the already stored potential in the devices which contained discharges to give a potential of approximately $2V_m$. This potential difference between the face 8 and the cathode electrode 4 is greater than $\frac{1}{2}V_s$ the discharge striking voltage. In the devices which contained no discharges, the potential difference is approximately V_m and is insufficient to cause a discharge to strike. Thus only previously visible discharges are re-struck and they remain so when the conductor 10 is returned to ground potential. As described previously, the on/off time ratio of the discharge determines the subjective brightness of the display.

In order to erase a discharge from the display it is necessary to increase the potential of the appropriate cathode conductor to extinguish the discharge and thereafter return it to zero potential, and then reduce the potential of the conductor 10 to zero in the form of a step. Re-application of a pulse to conductor 10 will restrike discharges in all devices except those in which the discharges were erased whilst their conductor 10 was at a potential V_m . As explained previously for a single device, the continuation of extinguishing and restriking pulses does not cause restriking in the "erased" cells.

A further advantage of an array of such discharge devices is that a new discharge may be struck in a device of one row (or column) while discharges already existing in other devices in that row (or column) are temporarily extinguished. For instance, while the maintaining voltage V_m is removed from all the devices through the application of pulses $(V_m - V_e)$, pulses of $\pm\frac{1}{2}V_s$ may be applied to selected anode and cathode conductors respectively to establish a discharge which is extinguished at the end of the pulse. When the next restriking pulse is supplied to all the subsidiary anode conductors 10 then the newly extinguished discharges are re-struck with the previously extinguished discharges. Alternatively, when the maintaining voltage has been re-applied following an extinguishing pulse, but before the next restriking pulse, pulses of $\pm\frac{1}{2}(V_s - V_m)$ may be applied to the selected anode and cathode conductors. This action permits a reduction in the power handling requirements of the drivers required for each row and column; that is, the driver is not required to be able to supply a current to maintain a large number of discharges while being able to operate simultaneously at high voltage levels to strike additional ones.

The striking pulse is normally connected to all of the subsidiary anode conductors 10 simultaneously. As an alternative a number of rows, say, may be grouped and restriking pulses applied at a different time. For instance, if the display is of lines of alphanumeric characters, the overall brightness may be set a low level, but certain lines of characters displaying important information may be made to appear brighter by applying the restriking pulses at an earlier time after the extinguishing pulses. Alternatively, the contrast of the line could be varied between bright and very dim at relatively long half-second intervals to give a flashing effect.

What I claim is:

1. A visual display device incorporating a two-coordinate array of gas-filled cold-cathode direct-current

discharge devices adapted to enable a variable brightness display to be produced and producing the variation without applying to any conductor of the panel a potential in excess of a maintaining potential comprising a block of electrically insulating material containing a plurality of gas-filled apertures arranged in a two-coordinate array; a first end plate of electrically insulating material fixed to the block and sealing one end of the apertures, a plurality of first electrodes, one for each discharge device, carried by a face of the first end plate adjacent one end of the aperture, a plurality of electrical impedance elements, carried by said face of the first end plate, individual elements being connected to individual first electrodes, a first set of electrical conductors also carried by said face of the first endplate, individual conductors interconnecting the impedance elements associated with particular values of one co-ordinate of the array; a second set of electrical conductors adjacent the other end of the apertures, individual conductors of the second set forming second electrodes of the discharge devices associated with particular values of the other co-ordinate of the array; a second endplate of electrically insulating material fixed to the block and sealing the other ends of the apertures and adapted to retain the second set of electrical conductors, a third set of electrical conductors carried by the second end plate, means for capacitively coupling individual conductors of the third set to the discharge devices associated with particular values of said other co-ordinate of the array and said individual conductors of the third set being more remote than the second electrodes from the first electrodes.

2. A visual display device as claimed in claim 1 in which the conductors of the second set extend across the end faces of the apertures.

3. A visual display device as claimed in claim 1 in which the conductors of the third set are carried by a face of the second end plate adjacent the block.

4. A visual display device as claimed in claim 1 in which the conductors of the third set extend in a direction parallel to the conductors of the second set.

5. A visual display device as claimed in claim 4 in which the means for capacitively coupling the conductors of the third set and the discharge devices comprises a layer of dielectric material carried by a face of the second end plate and covering the third set of electrical conductors.

6. A visual display device as claimed in claim 1 in which the means for capacitively coupling the conductors of the third set and the discharge devices comprises a layer of dielectric material carried by a face of the second end plate and covering the third set of electrical conductors.

7. A visual display device as claimed in claim 6 in which the portions of said layer of dielectric material which are adjacent to and which cover the third set of conductors and in registration with the apertures are of less thickness than the remainder of said layer.

8. A visual display device as claimed in claim 6 in which the dielectric material is solder glass.

9. A visual display device incorporating a two-coordinate array of gas-filled cold-cathode direct-current discharge devices, adapted to enable a variable brightness display to be produced and producing the variation without applying to any conductor of the panel a potential in excess of a maintaining potential, each discharge device of the array having a gas filled discharge space, a first electrode communicating with the discharge space, an impedance element connected to the first electrode, a second electrode in communication with the discharge space, a third electrode more remote than the second electrode from the first electrode, means for capacitively coupling the third electrode to the discharge device, the array also comprising a first set of electrical conductors, individual conductors of the set interconnecting the impedance elements of the discharge devices associated with the individual values of one co-ordinate of the array, a second set of electrical conductors, individual conductors of the set interconnecting the second electrodes of the discharge devices associated with individual values of the other co-ordinate of the array, and a third set of conductors, individual conductors of the third set interconnecting the third electrodes of the discharge devices associated with individual values of said other co-ordinate of the array.

10. A visual display device as set forth in claim 9 in which the means for capacitively coupling the third electrode and the discharge space comprises a layer of dielectric material between the discharge spaces of the array and the third electrode of the array having areas of reduced thickness in registration with the gas filled discharge spaces.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,876,906
DATED : April 8, 1975
INVENTOR(S) : Frank Walters

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Cover page, after item [21], insert:

--[30] Foreign Application Priority Data
June 21, 1972 Great Britain 28923/72--.

Column 8, line 10, after "and" insert --which
are--; line 27, "device" should read --space--.

Signed and Sealed this

second Day of September 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks