United States Patent [19]
Eisenberg et al.

[11] **3,778,673**
[45] **Dec. 11, 1973**

[54] **LOW POWER DISPLAY DRIVER HAVING BRIGHTNESS CONTROL**

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[22] Filed: **June 21, 1971**

[21] Appl. No.: **154,729**

[52] **U.S. Cl.** **315/169,** 315/170
[51] **Int. Cl.** **H05b 37/00**
[58] **Field of Search** 315/169, 168, 170

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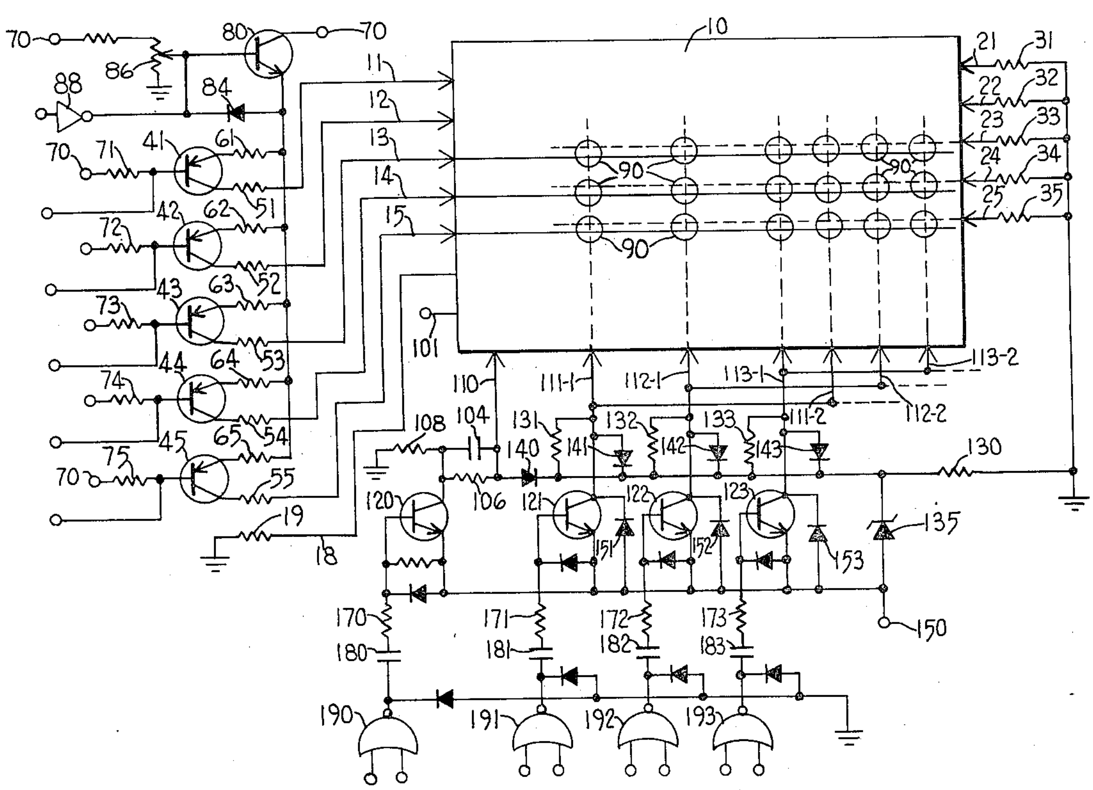
[57] **ABSTRACT**

Low power drive apparatus connected for operating display devices including a plurality of gas-filled cells and gas communication channels extending between adjacent columns of cells for scanning of them by glow transfer from column to column. The driving apparatus includes series-connected drive circuits for the display control anodes of the devices, operated in the current-controlling mode of the input data signals. The display anode drivers are connected as controllable current sources which do not saturate when activated. A variable voltage device is connected to the current drivers for controlling the brightness of the display by regulating the amount of current conducted to the display cells when activated.

7 Claims, 5 Drawing Figures



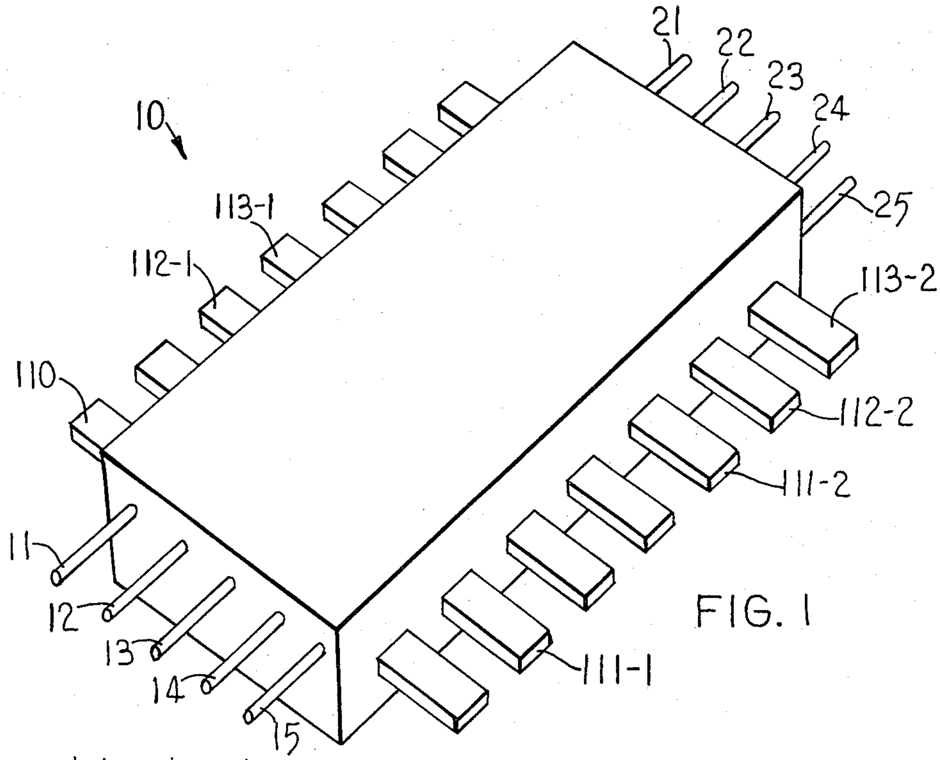


FIG. 1

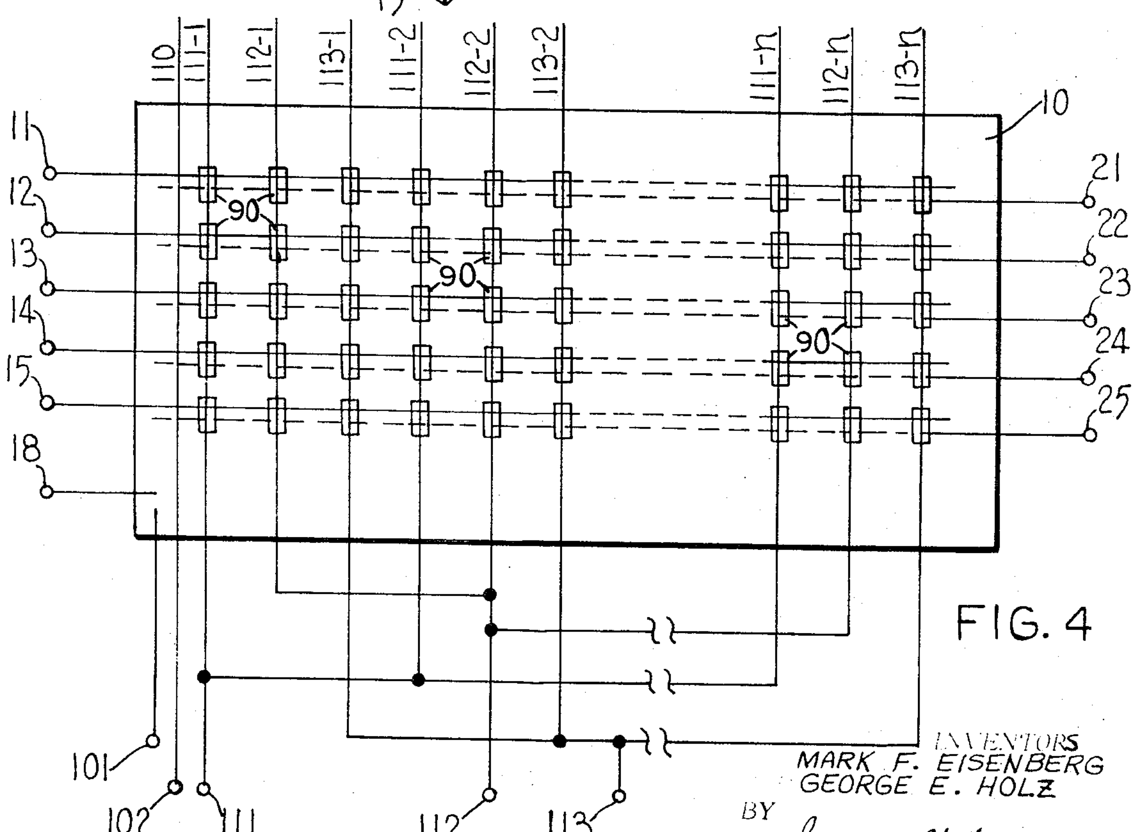


FIG. 4

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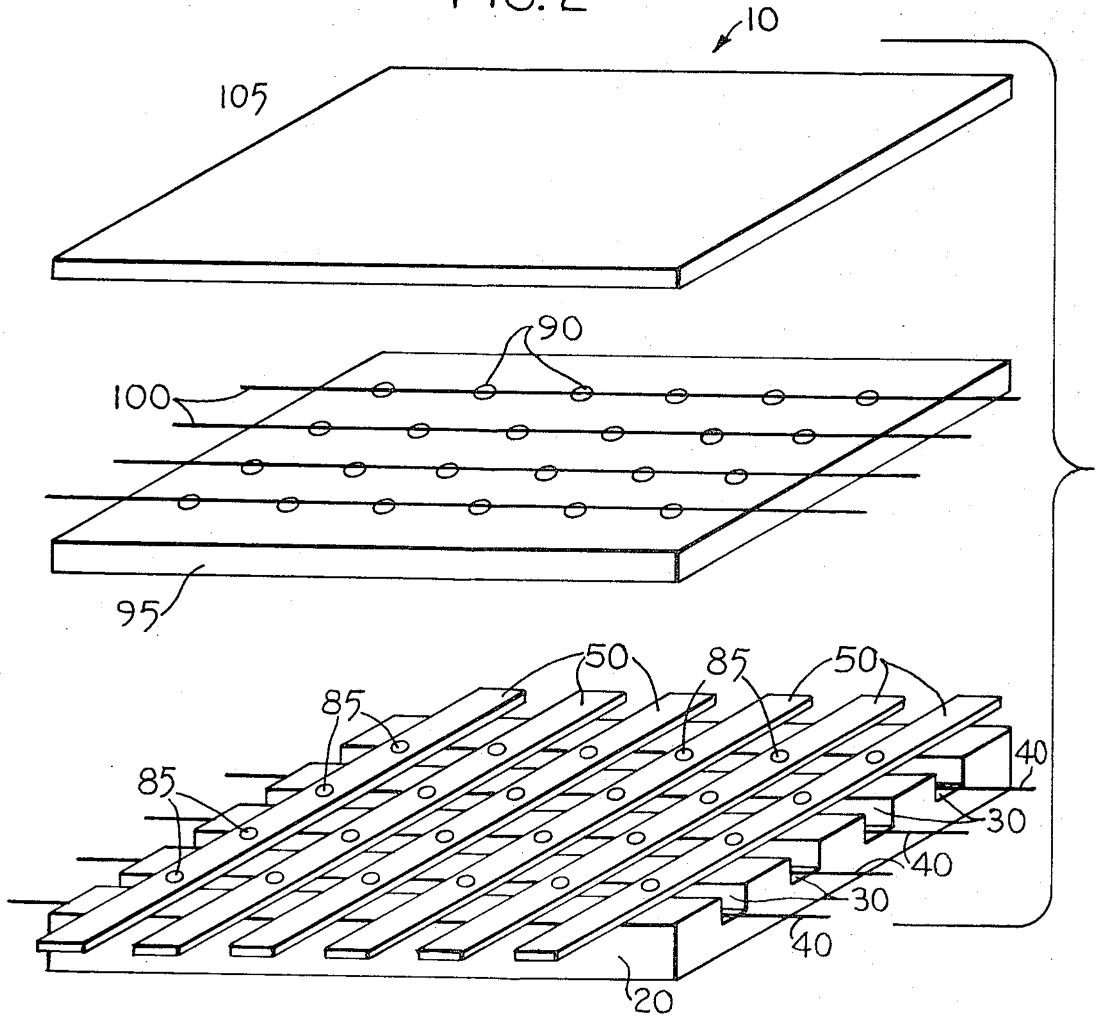
FIG. 2



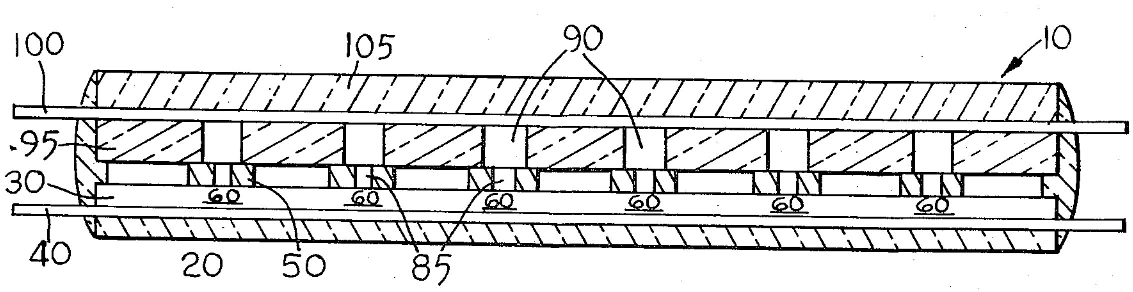


FIG. 3

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PATENTED DEC 11 1973 3,778,673

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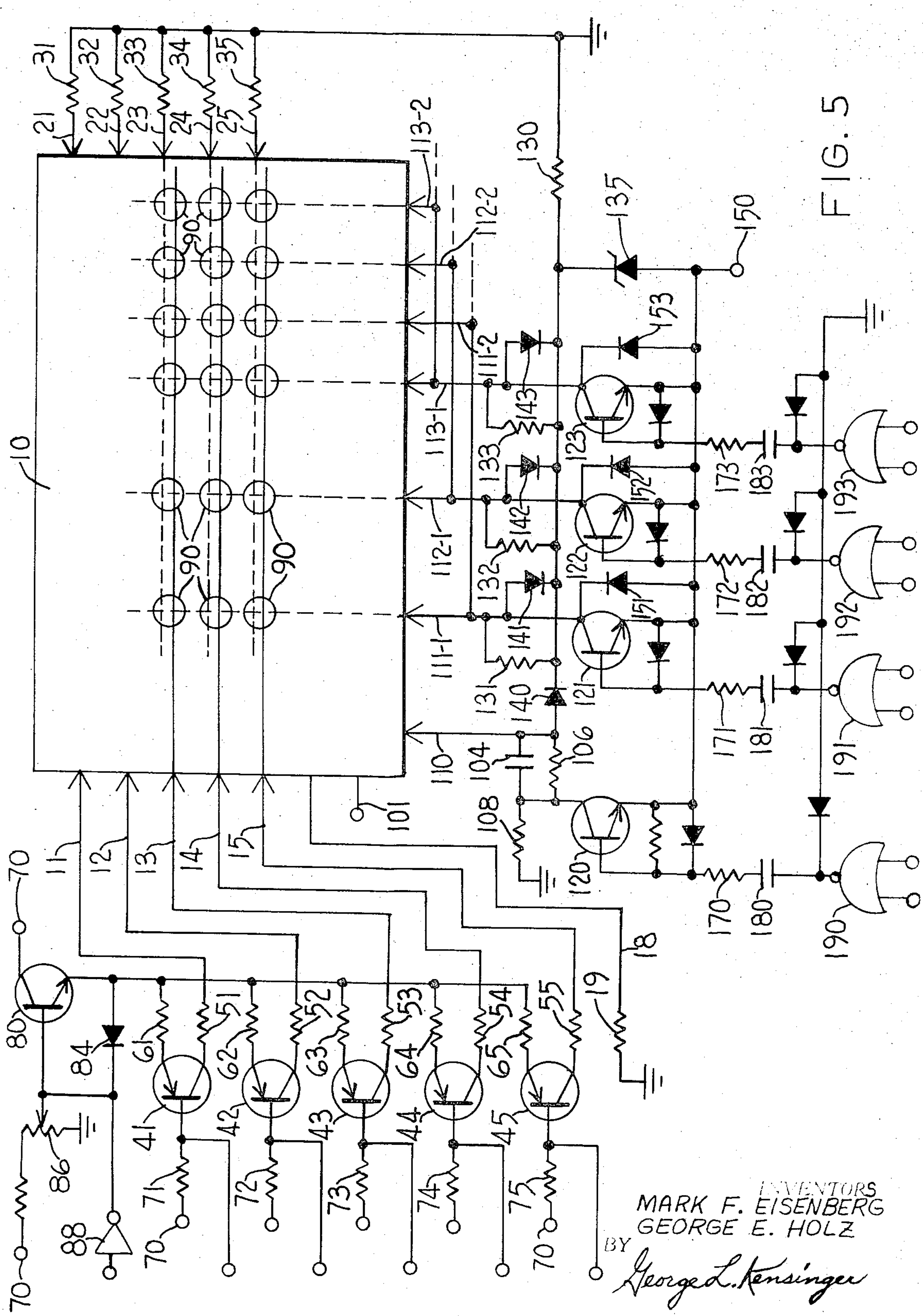

FIG. 5

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LOW POWER DISPLAY DRIVER HAVING BRIGHTNESS CONTROL

BACKGROUND OF THE INVENTION

The invention relates to low power drive apparatus for operating multiple element display devices. More particularly, the invention relates to efficient current drivers for the display control electrodes of gas discharge display panels. Brightness control apparatus for such display drivers is also provided.

Display panels having a plurality of gas-filled cells within the body of the panel have been available commercially for some time. One such device is known as the SELF-SCAN panel display, described in Ogle & Holtz, Ser. No. 850,984, filed Aug. 18, 1969.

The SELF-SCAN panel display includes a layer of scan cells and a layer of display cells, with each scan cell communicating with a display cell. Gas communication channels between adjacent columns of scan cells provide for a selected flow of excited gas particles for preferential transfer of glow discharge between them. This glow transfer admits of internal scanning of the columns of cells in the panel, which greatly reduces the amount of drive and selection circuitry necessary for operating the device. Both the cost of the display and the amount of power utilized in operating the display are decreased by this reduction in external drive and selection circuitry.

Such display panels include a plurality of cathode electrodes crossed by a set of suitably loaded rear or scan anodes along which glow is transferred during scanning. In addition, a set of display anodes positioned above the cathodes generally parallel to the scan anodes is provided for transferring glow discharge from the scan cells into selected ones of the display cells for displaying messages.

A considerable amount of power is still dissipated in the operation of these devices, however, especially when they are enlarged to increase the number of display cells. Under some circumstances, the amount of power consumed within the driving apparatus is undesirable. The display anode drivers usually have been shunt-connected units and dissipated a considerable amount of power in their sizable current-limiting resistors. Also, each of the display anode drivers was usually clamped to a reference terminal which wasted additional current and power. The NPN transistors employed in the anode drivers were relatively inexpensive, but, unfortunately, too much power is wasted in the shunt-mode operation of them.

It would be desirable to reduce the power dissipated in the display device and in the attendant circuitry to make battery operation more feasible, particularly in portable equipment where a limited amount of energy is usually available. The power dissipated in the display device itself, however, is determined primarily by the amount of voltage applied for initially establishing the gas discharge in the cells.

Also, the display anode drivers operated as switches which saturate when activated and are slow to turn off. This can interfere with the blanking of the display between successive sets of data signals. Furthermore, the brightness of the display cells was dependent on the conduction characteristics of the individual cells which can be different. The voltage drop across each activated cell determined the amount of current that it conducted and thus the brightness of its glow since the drivers were saturated and not controlling.

No convenient or efficient means for controlling the brightness of the display image was provided in the previously known apparatus. In some applications, as in dimly lit areas or when the display panel itself is surrounded by a dark frame or bezel, a brightness control is desirable since the viewer's eyes become acclimated to the average level of light provided in the total area of view. Under such conditions the light produced by the gas discharge in the display panel may be too bright and a means for controlling the brightness of the display is, therefore, needed.

SUMMARY OF THE INVENTION

Accordingly, an object of the invention is to reduce the amount of power required by apparatus for operating display devices having a plurality of light-producing cells.

Another object of the invention is to provide uniformity of brightness in the cells of gas discharge display devices and to provide a brightness control in the operating apparatus for such devices.

In accordance with the invention there is provided a current driver circuit including several independently controllable current-sources for connection to the display control electrodes of devices having an array of display elements or cells. The cathodes of the device may be energized sequentially in a scanning mode of operation in cooperation with a set of scan anodes, or may be sequentially addressed. The current sources for the display anodes include series-connected transistors and suitable current-limiting resistors for each of the display control anodes. In addition, a pulse-operable variable voltage gate is coupled to each of the display anode drivers to control selectively the amount of current which they conduct when activated, for regulating the brightness of the display.

DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention are made clear in the following detailed description and in the accompanying drawings wherein:

FIG. 1 is a perspective view of a multi-element display panel with which the invention may be utilized;

FIG. 2 is an exploded view and FIG. 3 is a sectional view of such a display panel;

FIG. 4 is a schematic representation of a display panel with its attendant control electrodes and matrix array of display cells; and

FIG. 5 is an electrical schematic circuit diagram of an exemplary low power apparatus for operating a display panel according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The illustrated apparatus is provided for operating display cells in a display device having an array of similar light-producing cells which are successively scanned in groups. It is particularly useful for operating display panels such as those described in the patent application Ser. No. 850,948 of Ogle and Holz and in the patent application Ser. No. 855,448 of J. A. Ogle, both filed Aug. 18, 1969. The display device is shown and described herein as panel 10. The panel may have substantially any desired size and shape, and it may include substantially any number of gas-filled display cells of the like. It also contains any suitable ionizable gas such as neon, argon, xenon, etc., singly or in combination, and usually a vapor of a metal such as mercury to reduce cathode sputtering.

Display panels having different numbers of cells appear in the various figures for illustrating the display device and the invention. The panel shown in FIG. 1 has six cathode columns 111-1 to 113-2 of five cells each and the structure of FIGS. 2 and 3 has five cathode columns 50 of four cells each. A greater number of cells are included in the schematic representation of the panel and the external connections for scanning its cells in FIGS. 4 and 5. The display cells 90 may be of any desired shape such as round (FIGS. 2, 3 and 5) or rectangular (FIG. 4).

Referring to FIGS. 1 and 4 a display panel 10, operable in accordance with the invention, includes an insulating housing of glass, ceramic, or the like having a plurality of display control electrodes 11, 12, ... 15 formed in an upper layer thereof and scan electrodes 21, 22, ... 25 formed near the base. They are preferably wires used as display control anodes and scan supporting anodes, respectively, in the operation of the device.

The cathode electrodes 111-1, 112-1, 113-1, ... 113-2 are preferably flat strips, each having a series of holes or apertures for a column of display cells. The cathodes are parallel to each other and are oriented at an angle, preferably 90°, to the scan anodes 21–25. Each crossing of them defines a scan cell. A cathode aperture is located at each crossing for priming an associated display cell 90. Each cathode 111-1, ... 113-2 lies along a column of cells, and each anode lies along a row of cells. Therefore, each column of cathode apertures is associated with a column of cells and each row of cathode apertures, defined by adjacent cathodes, lies along a row of cells. Each scan cell includes a portion of one of the scan control anodes 21–25, the associated portion of a cathode 111-1, ... 113-2 above it, and the volume of gas between these electrode portions. The scanning cells are identified by the anode and cathode which cross them.

The system of the invention is especially suited for use with a display panel 10 of the type known as a SELF-SCAN panel and shown in FIGS. 2 and 3. This type of panel includes a bottom plate 20 of insulating material, such as glass or ceramic, having a plurality of parallel slots 30 formed in the top surface thereof. Electrodes 40, which are used as scanning anodes in one mode of operation of the panel, are seated in each of the slots 30, and electrodes 50, used as cathodes for scanning and display, are seated on or in the top surface of plate 20. Each cathode electrode 50 crosses each anode electrode 40, and each crossing defines a scan cell 60. The cathodes include rows of tiny apertures 85, each of which is located at a scan cell. The scanning cells 60 are arrayed in rows and columns, and each cathode 50 is oriented along a vertical column of scanning cells in the panel as illustrated.

The panel 10 includes an insulating plate 95 disposed over the cathodes 50 and having apertures or display cells 90 arrayed in rows and columns, with each cell 90 being positioned over and in operative relation with a cathode aperture 85 and a scan cell 60. Display anode wires 100 are disposed on or in the top surface of the insulating plate 95, and each is aligned with a row of display cells 90. A glass cover plate 105 completes the panel. The panel is filled with a suitable ionizable gas such as neon, argon, xenon or the like, or mixtures of such gases and a vapor of mercury is usually included to minimize cathode sputtering.

The operation of a SELF-SCAN panel and the structural features thereof are described and claimed in copending application Ser. No. 850,984, filed Aug. 18, 1969. Briefly, the operation comprises applying operating potential to all of the scanning anodes 40 and applying operating potential sequentially and in turn to each of the scanning cathode electrodes 50, beginning, for example, at the left and proceeding to the right as seen in FIGS. 2 and 3. As each scanning cathode is energized, the associated column of scanning cells 60 is fired, and the operation is carried out sequentially throughout the panel. Simultaneously with the energization of each cathode 50, information signals are applied to selected display anodes 100. The display cells 90, associated with the energized anodes 100 and the energized scanning cells 60, are thus fired. The information signals on anodes 100 may change in accordance with the message to be entered or displayed, with each scanning cathode that is energized. As the panel is continuously scanned and information signals are entered, a stationary, but changeable, message made up of energized display cells can be viewed or sensed through the face plate.

In one form of the device the panel 10 includes a reset cathode 110, a keep-alive anode 18 and cathode 101, and a covering view plate of glass or the like as in FIGS. 4 and 5. In the completed panel 10, the plates and the various electrodes are hermetically sealed along their adjacent edges by a glass frit such as Pyroceram, or other suitable material. Reset cathode 110 may have a separate group of gas cells associated with it, if desired. The gas used in panel 10 is introduced in any suitable manner, for example, by means of a tubulation (not shown), secured to the bottom plate.

The cells usually are actuated beginning with the first column of scan cells and proceeding from column to column to the last column of cells in the device. A signal is generated to fire the cells associated with reset cathode 110 having terminal 102 to initiate the scanning cycle. The cathodes of the panel are connected in three groups, which may be described as phases, to terminals 111, 112 and 113, as shown in FIG. 4. The display cathode 111-1 associated with the first column of cells at the left-hand edge of the panel is designated a phase 1 cathode and every fourth cathode is connected in this group. The other cathodes are connected in the other groups as shown, including the last cathodes 111-*n*, 112-*n* and 113-*n*. A matrix array of display cells 90 is illustrated, associated with the cathodes 111, 112, 113. Any number of cells may be included in the array, of course, including cells in association with reset cathode 102, if desired. The keep-alive anode 18 and the keep-alive cathode 101, if included, are usually energized independent of the other electrodes.

Referring now to FIG. 5 in detail, a display system according to the invention includes a display panel 10 having a plurality of display cells 90. Display anodes 11–15 are associated with the rows of display cells and scan anodes 21–25 in the panel are coupled to a potential terminal (ground) by resistors 31–35, respectively. Cathodes 111-1, 112-1 and 113-1 are associated with the first three display columns at one end of the panel. The panel also includes a reset cathode 110 and cathodes 111-2...111-*n*, 112-2...112-*n*, 113-2...113-*n*, coupled in groups with cathodes 111-1, 112-1 and 113-1, respectively.

The cathodes are pre-biased at a potential determined by a Zener diode 135 connected in series with a resistor 130 between a negative reference terminal 150 and ground, as shown. Resistor 130 conducts continuously and conducts the major current for Zener diode 135. Parallel resistor and diode elements 131 and 141, 132 and 142, and 133 and 143 couple cathodes 111, 112 and 113 to the pre-biasing junction point. The energized anodes tend to pull up the potential of the OFF cathodes which forward biases coupling diodes 140–143 to the pre-bias junction or bus.

Reset cathode 110 is pre-biased to the junction of resistor 130 and Zener diode 135 by diode 140 and its driver circuit includes an NPN transistor 120 and an energy storage circuit including capacitor 104 and resistors 106 and 108 as described in Eisenberg, et al, Ser. No. 21,756. The reset cathode driver is controlled by a logic or timing gate 190 through series-connected resistor 170 and capacitor 180.

Display cathodes 111, 112 and 113 are cyclically operated by current drivers including NPN transistors 121 – 123 and are clamped at the negative potential on reference terminal 150 by diodes 151-153, respectively. Driver transistors 121–123 are controlled by AND gates 191–193 through the series-connected resistor-capacitor elements 171 and 181, 172 and 182, and 173 and 183.

Glow discharges in the panel are initiated between reset cathode 110 and scan anodes 21–25. Reset cathode 110 is energized by applying timing or counting control signals to gate 190 which actuates transistor 120 to conduct the necessary discharge current for the reset cells. The first display cathode 111-1 is then energized by applying control signals to gate 91 for actuating driver transistor 121 as transistor 120 is cut off. The glow discharge between the reset cathode 110 and each of the scan anodes 21–25 is thus preferentially transferred from the reset column to the first display column at cathode 111-1.

Likewise, the glow discharge regions along display cathode 111-1 at the scan anodes may be preferentially transferred to the second display column along cathode 112-1 by actuating driver transistor 122 and turning off transistor 121. The glow discharge in the scan cells defined by cathodes 111, 112 and 113 and the scan anodes is propagated along the scan anodes in the device by successively actuating transistors 121–123 in a manner now well known.

In this apparatus the display control anodes of the display cells 90 are driven by controllable current sources including series-connected transistors 41–45 instead of shunt-connected current switches driven to saturation as before. The display anode electrodes 11–15 are coupled by resistors 51–55 to the collector electrodes of the controllable current source transistors 41–45. These coupling resistors protect the current source drivers from destructively high current levels in case an arc occurs in the panel and couples to a display anode. These resistors may be omitted if transistors of sufficiently high breakdown voltage rating and secondary breakdown immunity are utilized.

The conduction levels of current source drivers 41–45 for the display anodes are determined by current-limiting resistors 61–65, respectively, connected between them at one end and a common voltage source such as transistor 80 at their other ends. The base electrodes of these transistor current drivers are initially biased off by resistors 71–75 connected to a bias potential terminal 70. The input signals for the date to be entered or displayed are applied directly to the base electrodes of current source resistors 41–45 in this embodiment. Alternatively, the base electrodes of the anode drivers 41–45 may be coupled to a common voltage source such as transistor 80, with the input data signals being applied to the emitters of the driver transistors. This inverts the polarity of the data signals to be applied to the anode drivers 41–45 and reduces the current that must be conducted by the voltage source transistor 80, but increases the current requirements for the anode driver transistors themselves.

The illustrated brightness and blanking control circuit includes transistor 80 having its collector connected to bias terminal 70 and its emitter connected to the other ends of emitter resistors 61–65 of the display anode drivers. The base electrode of control transistor 80 is coupled by a diode 82 to the variable output terminal of potentiometer 86 or the like and to the output terminal of control signal inverter 88. A diode 84 also connects the emitter of transistor 80 to the output of inverter 88. Potentiometer 86 is connected in series with a resistor, if desired, between reference terminal 70 and ground, as shown.

A feature of this system is that the brightness of the display cells 20 is made independent of differences in the electrical characteristics of the cells. The display cells each initially break down or fire at a particular voltage level depending upon their individual physical characteristics. The cells may also support different voltage drops once they discharge and begin conducting current. If they are driven by saturated current switches as done previously, they conduct different amounts of current to the extent that the voltage drops across them are different. This can result in different levels of brightness of the cells which may be objectionable.

In the present circuit, however, drivers 41–45 for the display anodes 11–15 operate as current source drivers whose currents are independent of the display cell characteristics. The display anode currents are determined by the current-limiting resistors 61–65 of the current drivers 41–45, respectively, and by the voltage level applied to them by control transistor 80. Control transistor 80 is initially non-conducting and the display cells 90 in the panel are disabled or blanked even though the scan cells in the device are activated by the cathodes and the scan anodes. Each time input data signals are applied to the base electrodes of the display anode drivers 41–45, control transistor 80 is enabled through inverter 88 by a clock signal which enables the display anode drivers for a predetermined interval of time.

The level of current conducted by the display anode drivers 41–45 is determined by the setting of potentiometer 86, or an equivalent circuit or device, which biases control transistor 80. The conduction level of the display anode drivers and thus the brightness of the display illumination in the cells 20 is determined by the level of conduction in control transistor 80. No difference in the voltage breakdown characteristics of the display cells affects the amount of current conducted to them or their brightness.

Although the preferred embodiment of the invention has been described in detail, it should be understood that the present disclosure has been provided by way of example only. Many modifications and variations of the invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically disclosed.

What is claimed is:

1. Low power drive apparatus for display devices having an array of gas-filled display cells interconnected in groups and a plurality of energizing electrodes and a plurality of display control electrodes disposed in contact with the gas in different groups of the cells and extending out of the cells, said apparatus comprising a plurality of unidirectional constant current drivers coupled to a common potential terminal, each including a resistance connected in series with one of the display control electrodes to control ionization in the cells selectively at a predetermined current in the cells and each having a control terminal to activate the driver upon receiving input signals for data to be displayed by the device.

2. The low power drive apparatus for display devices of claim 1 wherein the constant current drivers comprise a plurality of common-emitter connected transistors coupled between the common potential terminal and the corresponding display control electrodes, with their base electrodes being connected as the control terminals for them.

3. The low power drive apparatus for display devices of claim 2 further comprising a variable voltage gate

having a control terminal and being connected to the common potential terminal for determining the amount of current that the current drivers conduct when activated by the input data signals to control the brightness of the display.

4. The low power drive apparatus for display devices of claim 1 wherein the constant current drivers comprise a plurality of common-base connected transistors having their base electrodes coupled to the common potential terminal, their collectors coupled to the corresponding display control electrodes and their emitters connected as the control terminals.

5. The low power drive apparatus for display devices of claim 11 further comprising a variable voltage gate having a control terminal and being connected to the common potential terminal for determining the amount of current that the current drivers conduct when activated by the input data signals to control the brightness of the display.

6. The drive apparatus for display devices of claim 5 wherein the variable voltage gate comprises a transistor operated in the active region and having its base-emitter circuit connected between a variable voltage device and the common potential terminal and its collector connected to a reference potential terminal.

7. The drive apparatus for display devices of claim 6 wherein the base-emitter circuit of the variable voltage gate transistor further comprises means for receiving blanking control signals for control of the display current drivers and the variable voltage device comprises a potentiometer.

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