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(71) Applicant:
CANON KABUSHIKI KAISHA
Tokyo (JP)

(72) Inventors:
- **Tsuroyama, Akira**
Ohta-ku, Tokyo (JP)
- **Mizutani, Hidemasa**
Ohta-ku, Tokyo (JP)
- **Takahashi, Masanori**
Ohta-ku, Tokyo (JP)
- **Ohshima, Masamichi**
Ohta-ku, Tokyo (JP)
- **Aratani, Shuntaro**
Ohta-ku, Tokyo (JP)
- **Ouchi, Toshimichi**
Ohta-ku, Tokyo (JP)

(74) Representative:
Pellmann, Hans-Bernd, Dipl.-Ing. et al
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4
80336 München (DE)

(54) **Display device using sub-pixels and driving method therefor**

(57) A display device includes a plurality of scanning electrodes and a plurality of data electrodes so as to form a multiplicity of pixels each comprising a plurality of sub-pixels having mutually different areas for displaying a plurality of gradation levels by application of an electric signal corresponding to given gradation data to each pixel. The display device is driven by applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period. A display device may be formed such that each pixel includes at least one sub-pixel corresponding to a first electrode and at least one other sub-pixel corresponding to a second electrode, wherein said first and second electrodes have their respective terminals which are disposed at one and the other of two mutually opposite edges of the display device.

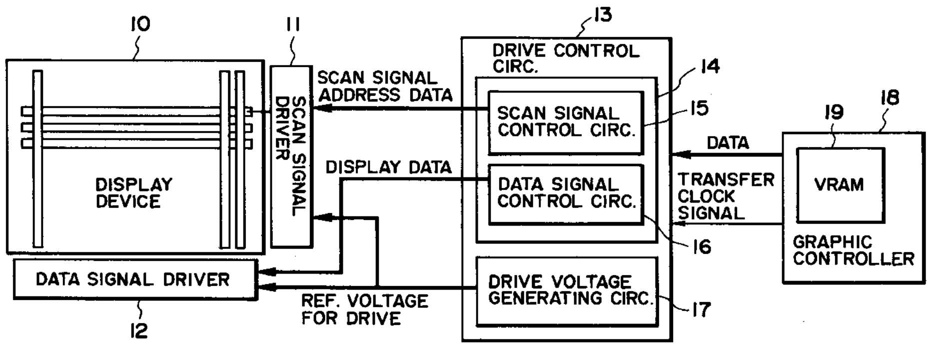

FIG. 3

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Description

FIELD OF THE INVENTION AND RELATED ART

The present invention relates to a display device suitable for use in various displays, inclusive of computer displays, home television receivers and various monitors for controllers, and a driving method for such a display device.

Hitherto, various proposals have been made regarding a method of realizing a multi-level gradation on a display device (or display panel) inclusive of the following.

(1) In a first type of method, an applied voltage to respective pixels is controlled according to an applied voltage-transmittance curve to obtain a desired level of luminance at the respective pixels.

This is typically adopted in an active matrix-type LCD (liquid crystal display device) using a TN (twisted nematic) liquid crystal. Further, in the case of using a ferroelectric chiral smectic liquid crystal, proposals have been made, e.g., as disclosed in U.S. Patents Nos. 4,712,877, 4,796,890, 4,824,218, and 4,776,676.

(2) In a second type of method, one frame scanning is divided into plural sub-frames (or fields) of scanning so as to modulate an ON/OFF time ratio to effect a multi-level gradational display, e.g., as disclosed in U.S. Patent No. 4,709,995. In the method (2), however, some difficulties can be encountered, such that the circuit becomes complicated and a high-speed scanning is required in order to suppress the occurrence of flicker, thereby posing a large load on the display device and the peripheral circuit therefor, leading to increased costs for production and operation.

Other methods include (3) a method using a multiplicity of pixels (sometimes also called "dots") each divided into a plurality of sub-pixels (also called "sub-dots") having mutually different areas and controlling the turning ON and OFF of the sub-pixels in various patterns to display multiple gradation levels, as disclosed in European non-examined application publications EP-A 261,898 and EP-A 453,033.

Specific examples of the method (3) and characteristic thereof will be described with reference to Figures 15A - 15C, each illustrating one pixel divided into areal ratios of 8:3:2:1.

Figure 15A illustrates one pixel which is vertically divided in a ratio of 4:1 and laterally divided in a ratio of 2:1 to form 4 sub-pixels having areal ratios of 8:4:2:1. The respective sub-pixels formed by the division may be supplied with prescribed electric signals to be independently turned on or off, thereby displaying 16 gradation levels (gray scale).

Figure 15B illustrates a further modification wherein one pixel is vertically divided in ratios of 2:1:2 and laterally in ratios of 1:1:1 to form 9 sub-pixels, which are provided with an electrode arrangement so that vertically outside sub-pixels and laterally outside sub-pixels are respectively simultaneously supplied with identical electric signals. Sub-pixels connected to an electrode S1 and sub-pixels-connected to an electrode S2 are designed to have an areal ratio of 4:1, and sub-pixels connected to an electrode I1 and sub-pixels connected to an electrode I2 are designed to have an areal ratio of 2:1, similarly as in Figure 15A, so that one pixel is substantially composed of sub-pixels having areal ratios of 8:4:2:1 to allow a display of 16 gradation levels similarly as in the pixel arrangement of Figure 15A. Further, in this case, the respective gradation levels can be displayed without causing a shift of optical gravity center, so that a smoother gradational display is allowed.

Figure 15C illustrates one pixel which is not vertically divided but only laterally divided into sub-pixels having areal ratios of 8:4:2:1. This pixel arrangement is accompanied with problems that each pixel provides different gradation levels while causing a shift of optical gravity center to result in an inferior display picture quality, and a higher lateral division density results in a lower aperture rate and a higher electrode arrangement density leading to an increased difficulty in production.

Figures 16A - 16D illustrate pixel arrangements for color display. Figure 16A shows one pixel including three color pixels. Figures 16B - 16D illustrate three types of division of each color pixel (also called "dot") into sub-pixels (also called "sub-dot(s)"). Each of Figures 16B - 16D illustrates a color pixel division allowing 16 gradation levels for each color pixel by division into two sub-pixels vertically and laterally.

Figure 16B illustrates a simple division scheme similar to the one shown in Figure 15A. Figure 16C illustrates a half symmetrical arrangement scheme so as to alleviate the optical gravity center shift only in the vertical direction. Figure 16D illustrates a sub-pixel arrangement scheme capable of alleviating the optical gravity center shift in both the vertical and the lateral directions. Each scheme allows a display of 16 gradation levels (4 bits) for each color and totally 4096 colors (12 bits) for each pixel.

In a color display, a 12 bits/pixel display allows a display of 4096 colors; a 15 bits/pixel display, ca. 32000 colors; and a 24 bits/pixel display, ca. 16.8x10^6 colors. Other levels of color display are also possible, but an explanation hereinafter will be made based on the division scheme.

Incidentally, various standardized display modes requiring different numbers of pixels are present and may preferably be displayed on a single display panel. For example, popular standardized display modes may include the following:

VGA mode requiring 640x480 pixels,
XGA mode requiring 1024x768 pixels, and

SXGA mode requiring 1280x1024 pixels.

On the other hand, the NTSC scheme as a standard home television scheme requires ca. 500 scanning lines, while the definition of the number of pixels is difficult by nature.

For instance, in case where a liquid crystal display panel having 1280x1024 pixels (SXGA) each having a sub-pixel-arrangement as shown in Figures 16A and 16C and capable of displaying 4096 colors, half degree of resolution is required for displaying a VGA picture on the display panel. In other words, 2x2 pixels in the 1280x1024 pixels may be used as one pixel according to the VGA-display mode. In this case, the number of displayable pixels is reduced to 640x512, whereby a VGA picture or a television picture can be displayed over almost the entire area of the SXGA panel at a half level of resolution.

On the other hand, if a VGA picture or a television picture is displayed on an XGA display panel by assigning one pixel of the XGA display panel to one pixel of the VGA or television picture, for instance, only a part of the display picture area is utilized for the display, leading to a broad non-display area, thus failing to effect a display on a full panel.

Further, there is also known a method of converting a VGA picture or a television picture into a picture data including 512x384 pixels and driving an XGA display panel while taking its 2x2 pixels as one pixel for the VGA or television picture, whereby a picture may be displayed on the full size of the display panel.

As described above, it is very effective to drive a display panel capable of a high resolution display (XGA, SXGA, or higher) while using its 2x2 pixels as one pixel of a medium resolution-level display mode (VGA, NTSC picture, etc.).

On the other hand, in the case of multiplexing drive of a display panel, e.g., a liquid crystal display panel, wherein the scanning electrodes (or scanning lines) are supplied with an electric signal (scanning signal) sequentially or in a time-sharing manner and, in synchronism therewith, the data electrodes (or data lines) are supplied with data signals to display a desired picture, if 2x2 pixels are driven as one pixel in the above-described manner, two scanning lines may be simultaneously selected to provide twice as fast a scanning speed. This is effective for providing an improved motion picture display quality and suppressing the flicker.

Figure 17 schematically illustrates an example of pixel arrangement of a liquid crystal display panel and Figure 18 is a partially enlarged view thereof for illustrating one pixel arrangement. Referring to these figures, the liquid crystal display panel includes (laterally) 1280 x (vertically) 1024 pixels at intersections of stripe electrodes. Each pixel is divided in three primary color pixels (dots) of R, G and B. The R, G and B color pixels (dots) are each present in a number of 1280x1024. Further, for effecting a gradational display, the scanning lines and data lines are respectively provided in non-uniform widths. The pixel division scheme is similar to the one shown in Figure 16C. More specifically, each color pixel is composed of two data lines having a width ratio of 2:1, and three scanning lines having width ratios of 2:1:2, of which the upper and lower scanning lines are designed to be supplied with an identical electric signal by short-circuitry or logic treatment in the drive IC. Figure 18 is an enlarged view of one pixel in Figure 17, allowing display of 12 bits/pixel, i.e., 4096 colors/pixel.

Figure 19 illustrates an example set of drive signal waveforms for effecting a high-resolution display according to an SXGA-mode of 1280x1024 on the panel of Figure 17. By using the waveforms, the scanning lines constituting the respective sub-pixels are driven line-by-line according to a basically non-interlaced mode. Each data line is supplied with a data signal of white (W) or black (B) so as to provide a desired display state. By sequentially scanning the first to 1024-th scanning lines each including two types of scanning lines (e.g., S1a (further divided into upper and lower lines) and S1b, ...), all the sub-pixels may be written independently into white (W) or black (B).

In this case, if one-horizontal scanning period is denoted by 1H, one picture rewriting period (one frame period) is 1H x (1024x2).

The waveforms are according to the line clear-simultaneous writing scheme wherein (sub-)pixels on a preceding scanning line are cleaned simultaneously with writing in (sub-)pixels on a subsequent scanning line. The set of drive signals shown in Figure 19 is merely one example.

On the other hand, in the case of a lower resolution display, the above-mentioned display panel may be driven at a higher speed by simultaneously driving a plurality of the scanning lines. For example, if two scanning lines each are driven simultaneously, one frame period will be reduced to 1Hx1024, i.e., twice as fast as the above not using simultaneous selection of two types of scanning lines. An example set of drive signal waveforms according to this scheme is shown in Figure 20. In this drive scheme, two types of scanning lines a and b (e.g., S1a and S1b) for each pixel are driven simultaneously (i.e., simultaneously supplied with a scanning signal), and this drive scheme may be referred to as an a-b/a-b simultaneous drive scheme, hereinafter.

Now, the number of displayable colors for each set of 2x2 pixels, will be considered.

As the scanning line a-b (e.g., S1a and S1b) are driven simultaneously, 4 gradation levels of 0 - 3 can be displayed for each color of pixel, and the number of gradation levels displayable by totally 4 pixels (2x2 pixels) is 3x4+1 = 13. Accordingly, the number of displayable colors according to this drive scheme is 13^3 = 2197 colors, which are less than 4096 colors inherently displayable by one pixel. Further, the drive scheme is accompanied with a picture quality deterioration due to a decrease in resolution to a half.

Apart from the above problem, a conventional display device is accompanied with the following problem.

Figure 21 shows an electrode or pixel arrangement of a display device disclosed in JP-A 7-270813 in which each pixel has a sub-pixel arrangement as shown in Figure 15B.

All the scanning electrodes (S1a ... S8b ...) are disposed on one substrate 21 having a terminal side on which scanning electrode terminals S1a, S2a, S3a ... S8a each connecting two thick scanning electrodes and scanning electrode terminals S1b, S2b, S3b, ... S8b each connected to one narrow scanning electrode, are all disposed.

Similarly, all data electrodes (I1a ... I10b) are disposed on the other substrate 22, having a terminal side 23, on which data electrode terminals I1a, I2a, ... I10a each connecting two thick data electrodes and data electrode terminal I1b, I2b, ... I10b each connected to one narrow data electrode, are all disposed.

Each device terminal electrical connection is similar to both of the devices shown in Figures 17 and 21 but, as for a physical electrode or wire connection, the one shown in Figure 21 is more common than the one shown in Figure 17, unless an expensive multi-layer electrode structure is adopted.

Such a display device has to be equipped with a scanning electrode driver and a data electrode driver attached thereto. In this instance, the terminal S1a and the terminal S1b for example have to be electrically isolated and independent from each other, so that their planar positions on the substrate 21 have to be separated from each other amply to some extent. Accordingly, the distances from the left edge of the substrate 21 to the respective terminals become different such that a distance (x1) to the terminal S1a is shorter than the distance (x2) to the terminal S1b.

As a result, when the output terminals of the driver are electrically and mechanically connected to the terminals S1a and S1b of the substrate 21, the positional determination becomes difficult, and the short circuitry or connection failure between the terminals is liable to be occur.

Further, a driver comprising a dive circuit for the scanning electrodes or a drive circuit for the data electrodes is disposed along only one side of the substrate 21 or 22, a drive heat generated from the driver results in a temperature distribution along the display device, which is liable to adversely affect a device, of which the display performances are liable to be affected by a temperature change.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a driving method for a display device having a higher resolution display mode and a lower resolution mode while accomplishing improvements in both the display speed and the picture quality.

Another object of the present invention is to provide a display device having pixels each comprising a plurality of sub-pixels, allowing easy connection with the drivers.

A further object of the present invention is to provide a display device having pixels each comprising a plurality of sub-pixels, less liable to develop an undesirable temperature distribution.

According to the present invention, there is provided a driving method for a display device of the type comprising a plurality of scanning electrodes and a plurality of data electrodes so as to form a multiplicity of pixels each comprising a plurality of sub-pixels including a larger sub-pixel and a smaller sub-pixel having mutually different areas for displaying a plurality of gradation levels by application of an electric signal corresponding to given gradation data to each pixel,

said driving method comprising applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period.

As a result, in the driving method according to the present invention, of adjacent at least two pixels or color pixels, larger sub-pixels may be selected in a horizontal scanning period and smaller sub-pixels may be selected independently in another horizontal scanning period, so that the number of gradation levels or colors is not reduced in the lower resolution mode drive. Further, as such larger sub-pixels are horizontally scanned simultaneously and such smaller sub-pixels are horizontally scanned simultaneously, respectively, the frequency of one frame for completing selection of all the scanning electrodes can be increased, thereby providing a display with little flicker or a good motion display.

According to another aspect of the present invention, there is provided a display device, comprising a plurality of pixels each comprising a plurality of sub-pixels including at least one sub-pixels corresponding to a first electrode and at least one other sub-pixel corresponding to a second electrode, wherein said first and second electrodes have their respective terminals which are disposed at one and the other of two mutually opposite edges of the display device.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a set of drive signal waveforms used in an embodiment of the driving method according to the invention.

Figure 2 is a partial plan view of a display device for illustrating an electrode arrangement used in the invention.

Figure 3 is a block diagram of a display apparatus including a display device for practicing a driving method according to the invention.

Figures 4 - 9 are respectively a waveform diagram showing a set of time-serial drive signals according to an embodiment of the invention.

Figure 10 is schematic plan view of a display device according to the invention showing an electrode arrangement and connection.

Figure 11 illustrates an electrode arrangement for one pixel in a display device according to the invention.

Figure 12 is a schematic plan view for illustrating a manner of attaching drivers to a display device according to the invention.

Figure 13 is a sectional view taken along a line A-A' in Figure 12.

Figure 14 is a schematic plan view of a driver used in the invention.

Figures 15A - 15C each show one unit pixel including a plurality of sub-pixels in a various pattern.

Figures 16A - 16D each show one color pixel including a plurality of sub-pixels in a various pattern.

Figure 17 is a partial plan view showing a pixel arrangement in a color display device.

Figure 18 is a view showing one unit pixel of a color display device.

Figures 19 and 20 are respectively a waveform diagram showing a set of time-serial drive signals used in a known driving method for a display device.

Figure 21 is a schematic plan view showing a pixel arrangement shown in a known display device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a waveform diagram showing a set of time-serially applied drive signal for principally illustrating a sequence of application of signals to the scanning electrodes, including a scanning selection signal comprising a pulse having a voltage V1 and a scanning non-selection signal having a voltage level Vref. Accordingly, a period for application of the pulse having a voltage V1 corresponds to a horizontal scanning period. At I are shown data signals applied to a data electrode.

Figure 2 is a schematic partial plan view for illustrating an electrode arrangement and a pixel arrangement of a display device used in the present invention.

S1a to S3b denote scanning electrodes and I1 to I3 denote data electrodes and, at intersections of these electrodes, larger sub-pixels PL1, PL2 and PL3 and smaller sub-pixels PS1, PS2 and PS3 are formed. Scanning electrodes corresponding to S4a and S4b and so on shown in Figure 1 are omitted from showing in Figure 2.

In this embodiment, scanning electrodes S1a and S2a corresponding to (or connected to) two larger pixels PL1 and PL2 are simultaneously supplied with a pulse having a voltage V1 as a scanning selection signal, and the other scanning electrodes are supplied with a voltage Vref as a scanning non-selection signal at that time. In a subsequent horizontal scanning period, scanning electrodes S1b and S2b corresponding to (or connected to) smaller pixels PS1 and PS2 are simultaneously supplied with a pulse having a voltage V1 to be selected simultaneously. As a result, the larger pixels PL1 and PL2 are placed in an identical display state (optical state), and the smaller pixels PS1 and PS2 are placed in an identical display state independent from that of the large pixels PL1 and PL2. In this instance, a unit pixel as a gradational display unit is composed of 4 sub-pixels PL1, PS1, PL2 and PS2. This is a low-resolution and high-speed first display mode. On the other hand, in a high-resolution and low-speed second display mode, the scanning electrodes may be sequentially selected in the order of S1a, S1b, S2a, S2b, S3a, S3b, ... in a non-interlaced mode, or sequentially selected in the order of S1a, S2a, S3a, ... S1b, S2b, S3b, ..., i.e., first only the scanning electrodes corresponding to the larger sub-pixels and then only the scanning electrodes corresponding to the smaller sub-pixels in an interlaced scanning mode. In this case, a unit pixel as a gradational display unit is composed of two sub-pixels, i.e., larger sub-pixel PL1 and a smaller sub-pixel PS1, so that a high-resolution display is effected.

Figure 3 is a block diagram of a display apparatus according to the present invention including a display device 10, a scanning signal driver 11 for applying a scanning selection signal or a scanning non-selection signal selectively to the scanning electrodes, and a data signal driver 12 for applying data signals for determining the display states of the pixels to the data electrodes,

The display apparatus further includes a control circuit 13 which in turn includes a drive control circuit 14 and a drive voltage generation circuit 17. The drive control circuit 14 includes a scanning signal control circuit 15 which supplies the scanning signal driver 11 with scanning signal address data including data for determining the order of selection of the scanning electrodes. The data is determined depending on the display mode, whereby the scanning electrodes are scanned (i.e., selected) sequentially in the above-described manner by the driver 11.

The dive control circuit 14 further includes a data signal control circuit 16 for supplying the driver 12 with display data corresponding to the scanning signal address data.

The drivers 11 and 12 receive reference voltages (e.g., V1, Vref, V2 and V3) for drive from the drive voltage generation circuit 17 and supply drive signals as shown in Figure 11 determined based on combinations of the reference voltages for prescribed durations by means of switching elements (not shown) to the scanning electrodes and the data electrodes.

The display apparatus further includes a graphic controller 18 for storing video data including gradation data in a VRAM 19 and supplies the video data read from the VRAM 19 together with transfer clock signals to the control circuit 13. For example, multi-value gradation data for each pixel may be converted into binary data for each sub-pixel (so as to provide a multi-value for a pixel concerned) by the graphic controller.

The display device 10 for monochromatic or color display used in the present invention may comprise, e.g., an electroluminescence device, an electrochromic device, a liquid crystal device, an electron discharge device, a plasma device or a micro-mirror device. Among these, a liquid crystal device may be particularly preferably used.

In the case of a liquid crystal device, the liquid crystal material used may preferably comprise a chiral smectic liquid crystal or nematic liquid crystal. Particularly, a chiral smectic liquid crystal is known to form a ferroelectric or anti-ferroelectric liquid crystal exhibiting a memory characteristic for a long hour and is desirably used for providing a high-resolution display. Further, a chiral nematic liquid crystal exhibiting a memory characteristic for a relatively short time may also be preferably used.

The scanning electrodes and data electrodes may be arranged to constitute either a simple matrix-type or an active matrix type device structure.

In the former case, functionally one electrode may be composed by a partially superposed combination of a high-resistivity transparent electrode and a low-resistivity opaque conductor, and the areal size of each sub-pixel is determined depending on the exposed area of the transparent electrode pattern. The electrode pattern similar to the one described with reference to Figures 17 and 18, but the electrode terminal disposition pattern may preferably be one described later with reference to Figure 10.

Further, the sub-pixel arrangement pattern may be similar to one shown in any of Figures 15A, 15B, 16B, 16C and 16D.

Drive signals applied to the scanning electrodes and data electrodes may be appropriately determined depending on a display medium constituting pixels and need not be restricted to those shown in Figure 1. Some examples thereof will be described in more detail with reference to embodiments described hereinafter. Further, scanning selection signals applied to scanning electrodes (e.g., S1a and S2a in Figure 1), which are horizontally scanned simultaneously, need not comprise pulses which rise and fall completely simultaneously with each other as shown in Figure 1, if two scanning electrodes are substantially simultaneously selected to determine display states.

Figure 1 shows an embodiment, wherein two unit pixels in a high-resolution mode display constitute one unit pixel in a low-resolution mode display. However, in case where a low-resolution mode display is performed three or four or more unit pixels, three or four or more scanning electrodes are simultaneously selected.

Particularly, in the above-mentioned low-resolution display mode, only a prescribed number (N) of scanning electrodes are preferentially scanned among totally M scanning electrodes (M>N). Herein, "preferential scanning" means that the prescribed number of scanning electrodes are scanned or selected at a higher frequency than the other scanning electrodes. The preferential scanning may preferably be applied to a partial rewrite display mode, which may be used to display a good quality of motion picture in a window defined in a whole picture area. Further, the sticking of a background picture may also be suppressed.

(Example 1)

In this example, a ferroelectric liquid crystal panel having a spacing between the substrates of 1.5 μm was driven under conditions including one horizontal scanning period of 30 μsec and drive voltages of ± 25 volts. Figure 4 shows a set of drive signal waveforms for a scanning sequence, whereby two "a"-scanning lines (wider scanning lines) are simultaneously scanned (referred to as "a-a simultaneous drive"), and then two "b"-scanning lines (narrower scanning lines) are simultaneously scanned (referred to as "b-b simultaneous drive") for two pixels each.

As a result, one frame (whole picture) scanning period is reduced to a half, thereby providing an increased scanning speed.

The number of colors displayable by 2x2 pixels, each having a sub-pixel arrangement pattern as shown in Figure 18, may be calculated as follows.

As for the number of gradation levels for each color, gradation levels of 0 - 15 for each of left and right 2x1 pixel pairs, and therefore 15x2+1 = 31 levels for 2x2 pixels, so that the number of colors displayable by 2x2 pixel pairs is 31^3 = 29791 colors.

Accordingly, compared with the formerly described "a-b/a-b simultaneous drive" (giving 2197 colors as displayable), the a-a/b-b simultaneous drive according to this embodiment provides an increased number of displayable colors (of more than ten times).

As is understood from the above comparison, in the case of performing a lower-resolution mode display on a higher-resolution display panel, it is possible to effect a high-speed and high-picture quality display by adopting the a-a/b-b simultaneous drive.

(Example 2)

This Example is the same as Example 1 except for adopting a different scanning order by application of scanning signals. Also in this example, the a-a/b-b simultaneous drive is performed similarly as in Example 1 but the vertical scanning is performed in two fields of first and second fields while selecting two scanning electrode simultaneously at a time as follows and as shown in Figure 5:

<1st field>

S1a - S2a

S3a - S4a

S5a - S6a

S7a - S8a

:

:

S1023a - S1024a,

<2nd field>

S1b - S2b

S3b - S4b

S5b - S6b

S7b - S8b

:

:

S1023b - S1024a.

As a result, "SXa" liens (X = 1 - 1024) corresponding to upper bits are preferentially selected for rewriting, a motion picture can be smoothly rewritten to provide a good picture quality.

(Example 3)

This example adopts a further different order from that in Example 2. The scanning order in the respective fields is as follows:

<1st field>

S1a - S2a

S5a - S6a

S9a - S10a

:

<2nd field>

S3a - S4a

S7a - S8a

S11a - S12a

:

<3rd field>

S1b - S2b

S5b - S6b

S9b - S10b

:

<4th field>

S3b - S4b

S7b - S8b

S11b - S12b

:

As shown above, by scanning the scanning electrodes with skipping, one frame operation is completed by four fields of vertical scanning. According to this embodiment, a high-quality picture with less flicker and smooth motion picture can be displayed even at a low frame frequency. A good picture quality can also be displayed by changing the order of the respective fields.

(Example 4)

This example adopts a different order of field selection from that in Example 2 as follows:

<1st field>

S1a - S2a

S7a - S8a

S13a - S14a

:

<2nd field>

S3a - S4a

S9a - S10a

S15a - S16a

:

<3rd field>

S5a - S6a

S11a - S12a

S17a - S18a

:

<4th field>

S1b - S2b

S7b - S8b

S13b - S14b

:

<5th field>

S3b - S4b

S9b - S10b

S15b - S16b

:

<6th field>

S5b - S6b

S11b - S12b

S17b - S18b

:

As shown above, one frame operation is performed in 6 fields by scanning the scanning electrodes with scanning. According to this embodiment, a high-quality picture with less flicker and smooth motion picture can be displayed even at a low frame frequency. A good picture quality can also be displayed by changing the order of the respective fields.

(Example 5)

This example adopts a set of drive waveforms (shown in Figures 6 and 7) by replacing a portion of the drive waveforms used in Example 2 (shown in Figure 5). Figure 6 shows a first frame and Figure 7 shows a second frame.

In this example, scanning signals having mutually polarity-inverted waveforms are applied to simultaneously selected scanning electrodes, e.g., S1a and S2a. Similarly, mutually polarity-inverted scanning signals are simultaneously applied to the scanning electrodes each for selection of the other scanning electrodes. In a subsequent field, a different order of mutually polarity-inverted scanning signals are sequentially applied to two scanning electrodes each, i.e., S1b - S2b, S3b -

S4b, ... Further, in a subsequent frame (Figure 7), two scanning electrodes each are again sequentially selected so that each scanning electrode receives a polarity-inverted scanning signal to effect a frame inversion drive scheme. As a result, the drive margin is improved so that a liquid crystal panel can be produced at a high productivity while ensuring a good picture quality.

(Examples 6 and 7)

A liquid crystal device was prepared by using a chiral nematic liquid crystal exhibiting bistability. Details of the operation principle of this type of liquid crystal device are disclosed in, e.g., EP-A 569,029 (corresponding to JP-A 6-230751.

More specifically, the liquid crystal material used was prepared by mixing a chiral dopant ("S811", available from Merck Co.) with a commercially available liquid crystal material ("KN-4000", available from Chisso K.K.) so as to provide a helical pitch of 3.6 μm. The device was prepared by providing a pair of electrode plates with a rubbed 100 nm-polyimide alignment film and assembling the electrode plates so that their rubbing directions were parallel and opposite to each other and the cell gap became 2 μm.

The liquid crystal device could be driven for writing under conditions including reset pulse voltages of ±20 volts, writing voltages of ±2.5 volts, data signal voltage of ±1.5 volts and one-line writing time of 300 μsec.

The liquid crystal device was driven by switching between a high resolution mode wherein all the scanning lines were independently scanned, and the above-mentioned a-a/b-b simultaneous drive mode, whereby display at respective resolutions could be attained.

(Example 8)

The drive sequence shown in Figure 4 (Example 1) and Figure 5 (Example 2) were respectively used for a partial rewrite scanning wherein a portion to be rewritten was preferentially scanned by detecting a data change by the graphic controller 18 in the apparatus of Figure 3 and supplying the data to the drive control circuit 13. As a result of adopting the a-a/b-b simultaneous drive mode in the partial rewrite scanning, a good picture quality display could be performed.

Incidentally, a high-resolution display may be performed on the whole or a part of the picture area by scanning all the scanning electrode in the related area according to the above-mentioned non-interlaced or interlaced scanning scheme.

(Example 9)

In this Example, Example 8 is modified by including an additional display mode wherein a partial rewrite scanning is performed by selecting only scanning electrodes S1a, S2a, S3a, S4a ... corresponding to larger-area sub-pixels and not selecting scanning electrodes S1b, S2b ...

For example, in a first display mode for rewriting the picture over the entire picture area, all the scanning electrodes are selected according to the non-interlaced or interlaced scanning scheme to effect a display of 16 gradation levels for each color and totally 4096 colors for each pixel.

Then, in a second display mode for a high-speed display at a low resolution, the set of drive signals shown in Figure 4 (used in Example 1) are used to display 31 gradation levels for each color and 29791 colors for 2x2 pixels. This second display mode is suitable for a motion picture display.

Then, in a third display mode, the above-mentioned additional display mode is adopted to perform a partial rewrite operation while attaching a greater importance to a high-speed operation.

According to the present invention, a low-resolution display with little flicker and suitable for motion picture display can be performed without decreasing the number of displayable gradation levels or colors.

Figure 10 illustrates a display device according to another embodiment of the present invention.

In the display device, a substrate 21 is provided with all the scanning electrodes, odd-numbered a terminals S1a, S3a, S5a, S7a ... each short-circuiting two scanning electrodes are disposed on a left-side terminal region 25, and even-numbered a terminals S2a, S4a, S5a, S8a ... each also short-circuiting the scanning electrodes are disposed on a right-side terminal region 26.

On the other hand, a group of scanning electrodes each disposed between the short-circuitted two electrodes are extended to provide terminals S2b, S4b, S6b, S8b ... which are disposed on the left-side terminal region 25, and the remaining group of scanning electrodes each disposed between the short-circuited two electrodes are extended to provide terminals S1b, S3b, S5b, S7b ... which are disposed on the right-side terminal region 26.

Similarly, a substrate 22 is provided with all data electrodes. Among terminals each short-circuiting two data electrodes, terminals I1a, I3a, i5a, I7a, I9a ... are disposed on an upper terminal region 24, and terminals I2a, I4a, I6a, I8a, I10a ... are disposed on a lower terminal region 23. On the other hand, among terminals each connected to one data electrode, terminals I2b, I4b, I6b, I8b, I10b ... are disposed on the upper terminals region 24, and terminals I1b, I3b, I5b, I9b, I9b ... are disposed on the lower terminal region.

In Figure 10, each terminal is depicted in a narrower width than each electrode for easy comprehension of the arrangement, but the terminals actually have a larger width than the electrode in many cases where the terminals are disposed at a much higher density than that supposed from Figure 10.

The above-mentioned arrangement may be simplified for one pixel arrangement as shown in Figure 11, so that a terminal S1a for short-circuitted two scanning electrodes (first electrodes) and a terminal for one scanning electrode disposed between the two scanning electrodes may be regarded as being disposed on mutually opposite left and right edges, respectively, of one substrate.

On the other hand, a terminal I1a for short-circuitted two data electrodes (first electrodes) and a terminal I1b for one data electrode disposed between the two data electrodes may be regarded as being disposed on mutually opposite upper and lower edges of one substrate.

Figure 12 is a plan view for illustrating a peripheral arrangement of scanning electrode drivers 11 and data electrode drivers 12 attached to a display device 10 having a similar structure as the one shown in Figure 10.

Referring to Figure 12, the scanning electrode drivers 11 include flexible films 35 and 36 mounted with IC chips 41 and 42, respectively, for driving the scanning electrodes, and the data electrode drivers 12 include flexible films 37 and 38 mounted with IC chips 43 and 44, respectively, for driving the data electrodes. These flexible films are generally called TCPs (tape carrier packages) according to the TAB (tape-automated bonding) method.

TCPs 35 and 36 ar connected to circuit boards 31 and 32, respectively, for transmitting address signals and signals for controlling the operation of the IC chips 41 and 42. TCPs 37 and 38 are connected to circuit boards 33 and 34, respectively, for transmitting picture data and signals for controlling the operation of the IC chips 43 and 44.

As shown in Figure 13 which is a sectional view taken along a line A-A' in Figure 12, a TCP 36, for example, comprises a flexible film 49 comprising a resin such as polyimide and provided with conductor patterns 47 and 48, each comprising an electroconductive material, such as copper. Also an IC chip 42 is mounted on the film 49, and terminals of the IC chip 42 are connected with the conductor patterns 47 and 48. Further, the connecting parts are covered with a sealing material 50, such as silicon resin. The conductor pattern 47 forms output terminals for supplying drive signals, which are connected to scanning electrode terminals on the substrate 21 with a connecting member 46, such as an anisotropic conductor film. The conductor pattern 48 forms input terminals for the IC chip 47, which are connected to terminals of the print circuit board 32 with a connecting member 45, such as an anisotropic conductor film or solder.

Figure 14 is a schematic plan view of a TCP including one IC chip.

The patterned conductors 47 and 48 as the terminals are respectively arranged along two sides of the flexible film 49.

Accordingly, regarding the arrangement of scanning electrode terminals on the substrate 21, compared with the arrangement of terminals including different distances from a substrate edge as shown in Figure 21, the arrangement shown in Figure 10 of terminals having an identical distance to a substrate edge allows a simpler positional alignment and a simpler pattern of conductors 47, thus being economically advantageous. Further, it is practically impossible to realize a terminal arrangement pattern as shown in Figure 17 unless a multi-layer conductor disposition pattern including a disposition of an intermediate insulating layer is adopted.

Further, according to the arrangement shown in Figure 10 of the present invention, it is possible to reduce the rate of occurrence of connection failures, such as a short circuit and the opening of a connection.

The drivers are attached to both upper and lower edges and/or both left and right edges of the display device 10.

In the embodiment shown in Figure 10, the terminal arrangement according to the present invention is adopted for both the scanning electrodes and the data electrodes. However, if the sub-pixel arrangement is modified so as to be achieved only by division in a vertical direction (e.g., as one shown in Figure 8 of JP-A 7-270813), the terminal arrangement according to the present invention may be applied to only the scanning electrodes.

Further, in the embodiment of Figure 10, among the terminals for two adjacent pixels, the terminals S1a and S2b are disposed on one side, and the terminals S1b and S2a are disposed on the other opposite side. This is for equalizing the loads on both sides of IC chips for driving the electrodes.

Accordingly, although terminals S1a, S2a, S3a ... S8a may be disposed on one side and terminals S1b, S2b, S3b, .. S8b may be disposed on the other side as another embodiment, but the embodiment of Figure 10 is preferred to such another embodiment.

The display device of Figure 10 may be suitably driven by using, a set of scanning signal waveforms and data signal waveforms, e.g., as shown in Figure 4.

More specifically, from scanning electrode drivers attached to both sides of the substrate, a scanning selection signal is simultaneously applied to scanning electrode terminals S1a and S2a. As shown in Figure 4, the scanning selection signal includes a pulse of one polarity for simultaneously clearing (or erasing or resetting) sub-pixels on a selected scanning electrode, a writing pulse of the other polarity and a small pulse of one polarity for preventing crosstalk.

At this time, the other terminals are supplied with a reference voltage as a scanning non-selection signal.

Then, scanning electrode terminals S1b and S2b are simultaneously supplied with a scanning selection signal to determine display states of sub-pixels on the selected scanning electrodes.

In synchronism with the application of such a scanning selection signal, data electrode terminals (I1a, I1b, I2a, I2b, .. I10a, I10b ...) are supplied with data signals I (including a B signal for providing a dark display state and a W signal for providing a bright display state).

As a result of the above-mentioned steps, the display states of two pixels each disposed along a direction of extension of data electrodes, are determined.

In the above-described manner, the display device 10 is supplied with scanning selection signals and data signals always from the drivers disposed on four sides including the upper and lower sides and the left and right sides, only a reduced temperature difference can be developed at any points over the display device 10. As a result, even a device having a temperature-dependence of display performance can be driven to provide an equally good display state similarly as a device having little temperature-dependence of display performance.

As described above, the drive waveform shown in Figure 4 is suitable for effecting a high-speed display at a number of pixels which is smaller than the number of pixels potentially displayable by the device. For example, in case where the display device shown in Figure 10 has 1280x1024 pixels, mutually adjacent 2x2 pixels may be driven corresponding to one pixel in order to display a VGA picture comprising 640x480 pixels. Thus, by developing one pixel display state of a picture over four pixels of the device, a VGA picture can be displayed in an enlarged size by using 1280x960 pixels of the display device.

In this instance, if plural scanning electrodes connected to larger-area sub-pixels are first selected simultaneously and then plural scanning electrodes connected to smaller-area sub-pixels are selected simultaneously among the scanning electrodes for the adjacent pixels to determine the display states of such adjacent plural pixels in a direction of extension of the data electrodes, a high-speed display becomes possible without decreasing the number of displayable gradation levels.

In the case of an ordinary display mode, one frame scanning period may be divided into at least two field scanning periods, so that scanning electrode terminals S1a, S2a, S3a ... S8a are sequentially supplied with a scanning selection signal in a first field, and scanning electrode terminals S1b, S2b, S3b ... S8b are sequentially supplied with a scanning selection signal, while supplying data signals to the data electrode terminals in synchronism with the application of the scanning selection signals.

The operation of the display device shown in Figure 10 has been described above with reference to an embodiment using a set of drive signals shown in Figure 4, but it is also possible to drive the device of Figure 10 for display by using a set of drive waveforms shown in any of Figure 5, Figures 6 and 7, Figure 8 and Figure 9.

As described above, according to the present invention, the complication of terminal arrangement pattern for the scanning electrodes and/or the data electrode can be prevented to allow an easy connection with the drivers. Further, as the drivers are connected to both sides of a display device, it is possible to obviate a temperature increase along one side of the device due to heat generation disposed thereat, so that it is possible to effect good operation of even a display device having temperature-depending display performances.

A display device includes a plurality of scanning electrodes and a plurality of data electrodes so as to form a multiplicity of pixels each comprising a plurality of sub-pixels having mutually different areas for displaying a plurality of gradation levels by application of an electric signal corresponding to given gradation data to each pixel. The display device is driven by applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period. A display device may be formed such that each pixel includes at least one sub-pixel corresponding to a first electrode and at least one other sub-pixel corresponding to a second electrode, wherein said first and second electrodes have their respective terminals which are disposed at one and the other of two mutually opposite edges of the display device.

Claims

1. A driving method for a display device of the type comprising a plurality of scanning electrodes and a plurality of data electrodes so as to form a multiplicity of pixels each comprising a plurality of sub-pixels including a larger sub-pixel and a smaller sub-pixel having mutually different areas for displaying a plurality of gradation levels by application of an electric signal corresponding to given gradation data to each pixel,

   said driving method comprising applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period.

2. A driving method according to Claim 1, wherein scanning electrodes corresponding to a region including pixels for which picture data has changed among said multiplicity of pixels are preferentially selected for rewriting the region.

3. A driving method according to Claim 1, comprising a mode of operation wherein one picture is formed by at least two vertical scanning periods including one vertical scanning period wherein only scanning electrodes corresponding to the larger sub-pixels are vertically scanned.

4. A driving method according to Claim 1, wherein a frame operation for selecting all the scanning elec-

trodes is divided into a plurality of vertical scanning fields so that all the scanning electrodes are divided into a plurality of groups each including a plurality of scanning electrodes receiving a scanning selection signal in an identical selection period and, in each vertical scanning field, the plurality of groups of scanning electrodes are selected sequentially while skipping at least one group of scanning electrodes for each selection.

5. A driving method according to Claim 1, wherein said plurality of sub-pixels of each pixel include a smallest-area sub-pixel and at least one pair of sub-pixels disposed at symmetrical positions with respect to the smallest-area sub-pixel.

6. A driving method according to Claim 1, wherein each pixel includes a display medium assuming two optical states.

7. A driving method according to any one of Claims 1 - 6, wherein each pixel includes a display medium comprising a chiral smectic liquid crystal.

8. A driving method according to any one of Claims 1 - 6, wherein each pixel includes a display medium comprising a nematic liquid crystal.

9. A driving method according to any one of Claims 1 - 6, comprising a plurality of operation modes using different numbers of or different sizes of pixels.

10. A display apparatus, including:

a display device comprising a plurality of scanning electrodes and a plurality of data electrodes so as to form a multiplicity of pixels each comprising a plurality of sub-pixels having mutually different areas, and
drive means for applying electrical signals to the respective sub-pixels depending on given gradation data;
said drive means including a scanning electrode drive circuit for applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period.

11. A display device, comprising a plurality of pixels each comprising a plurality of sub-pixels including at least one sub-pixels corresponding to a first electrode and at least one other sub-pixel corresponding to a second electrode, wherein said first and second electrodes have their respective terminals which are disposed at one and the other of two mutually opposite edges of the display device.

12. A display device according to Claim 11, wherein said first and second electrodes are scanning electrodes.

13. A display device according to Claim 11, wherein said first and second electrodes are data electrodes.

14. A display device according to Claim 11, wherein each pixel includes a pair of sub-pixels corresponding to the first electrode and a sub-pixel disposed between the pair of sub-pixels corresponding to the second electrode.

15. A display device according to Claim 11, wherein two adjacent pixels are disposed such that the first electrode for one pixel and the first electrode for the other pixel have terminals disposed at the mutually opposite edges of the display device.

16. A display device according to Claim 11, wherein two adjacent pixels are disposed such that each pixel includes a sub-pixel corresponding to the second electrode disposed between a pair of sub-pixels corresponding to the first electrode,

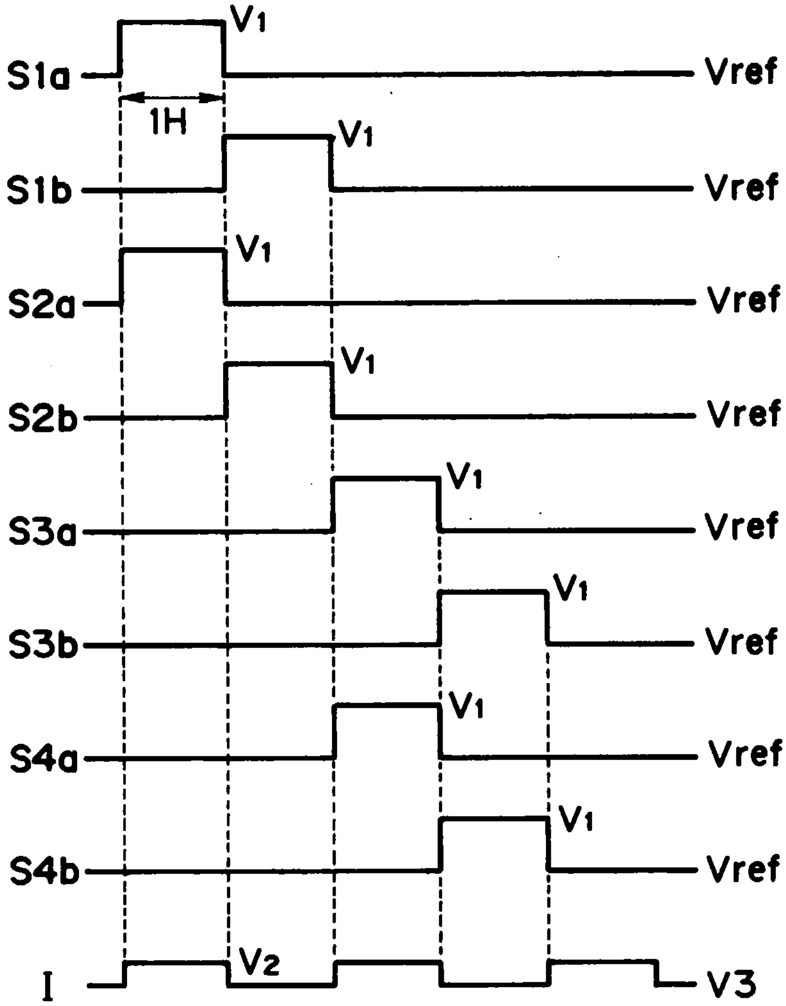
the terminal for the first electrode for one pixel and the terminal for the second electrode for the other pixel are disposed at one edge of the display device, and
the terminal for the second electrode for said one pixel and the terminal for the first electrode for said the other pixel are disposed at another edge opposite to said one edge of the display device.

17. A display device according to Claim 11, wherein a flexible film carrying an IC chip is attached to each of said mutually opposite two edges of the display device.

18. A driving method for a display device according to Claim 11, wherein each pixel comprises a plurality of sub-pixels having mutually different areas for displaying a plurality of gradation levels by application of an electric signal corresponding to given gradation data to each pixel,
said driving method comprising applying a scanning selection signal to a plurality of scanning electrodes corresponding to at least two sub-pixels having an identical area of adjacent two pixels in an identical selection period.

19. A driving method according to Claim 18, wherein said plurality of sub-pixels of each pixel include a smallest-area sub-pixel and at least one pair of sub-pixels disposed at symmetrical positions with respect to the smallest-area sub-pixel.

20. A driving method according to Claim 18, wherein each pixel includes a display medium assuming two optical states.


S1a
V1
Vref
1H
S1b
V1
Vref
S2a
V1
Vref
S2b
V1
Vref
S3a
V1
Vref
S3b
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Vref
S4a
V1
Vref
S4b
V1
Vref
I
V2
V3

FIG. 1

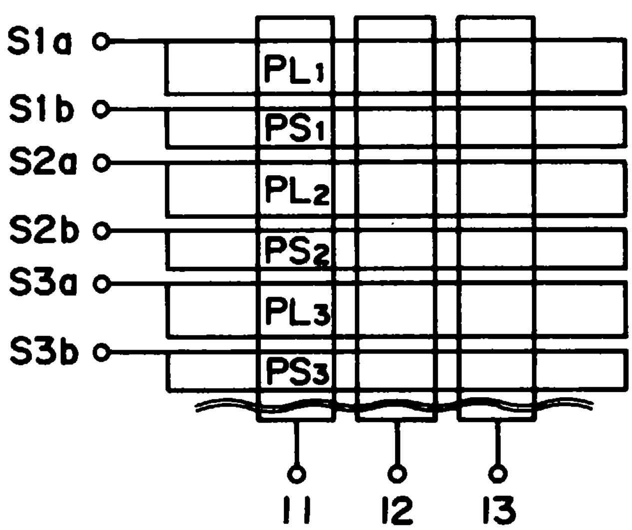

S1a
S1b
S2a
S2b
S3a
S3b
PL1
PS1
PL2
PS2
PL3
PS3
11
12
13

FIG. 2

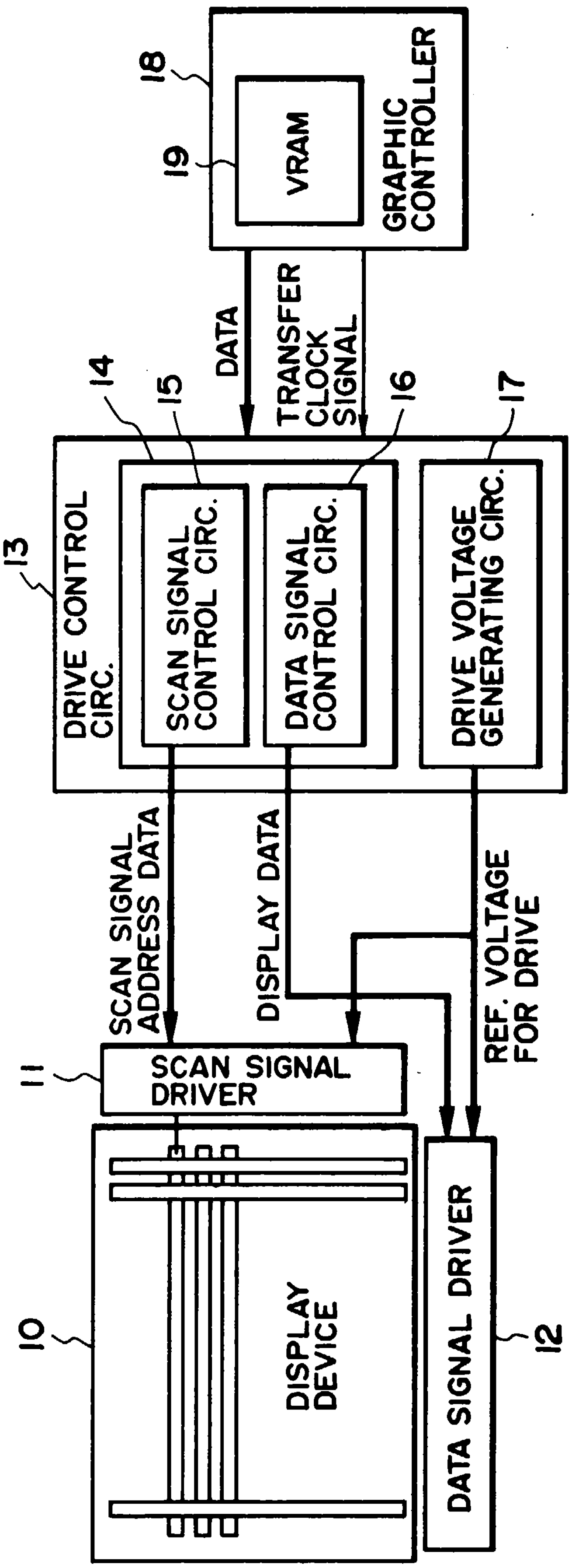

18
19
VRAM
GRAPHIC CONTROLLER
DATA
TRANSFER CLOCK SIGNAL
13
14
15
16
17
DRIVE CONTROL CIRC.
SCAN SIGNAL CONTROL CIRC.
DATA SIGNAL CONTROL CIRC.
DRIVE VOLTAGE GENERATING CIRC.
SCAN SIGNAL ADDRESS DATA
DISPLAY DATA
REF. VOLTAGE FOR DRIVE
11
SCAN SIGNAL DRIVER
10
DISPLAY DEVICE
12
DATA SIGNAL DRIVER

FIG. 3

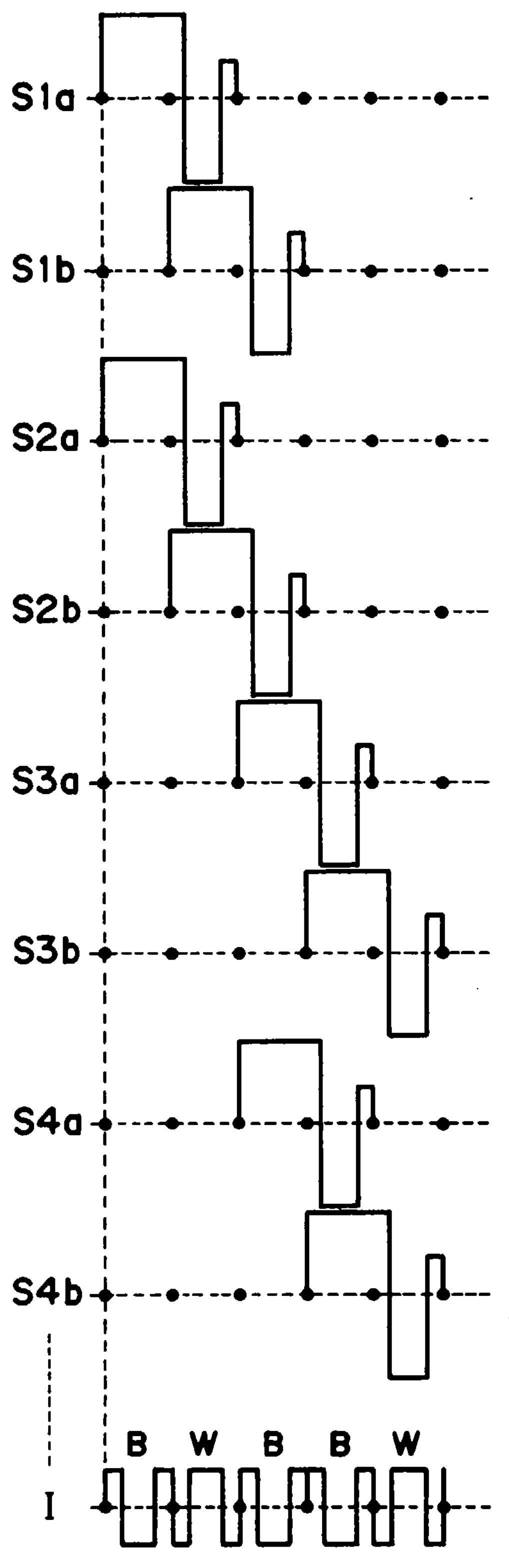


FIG. 4

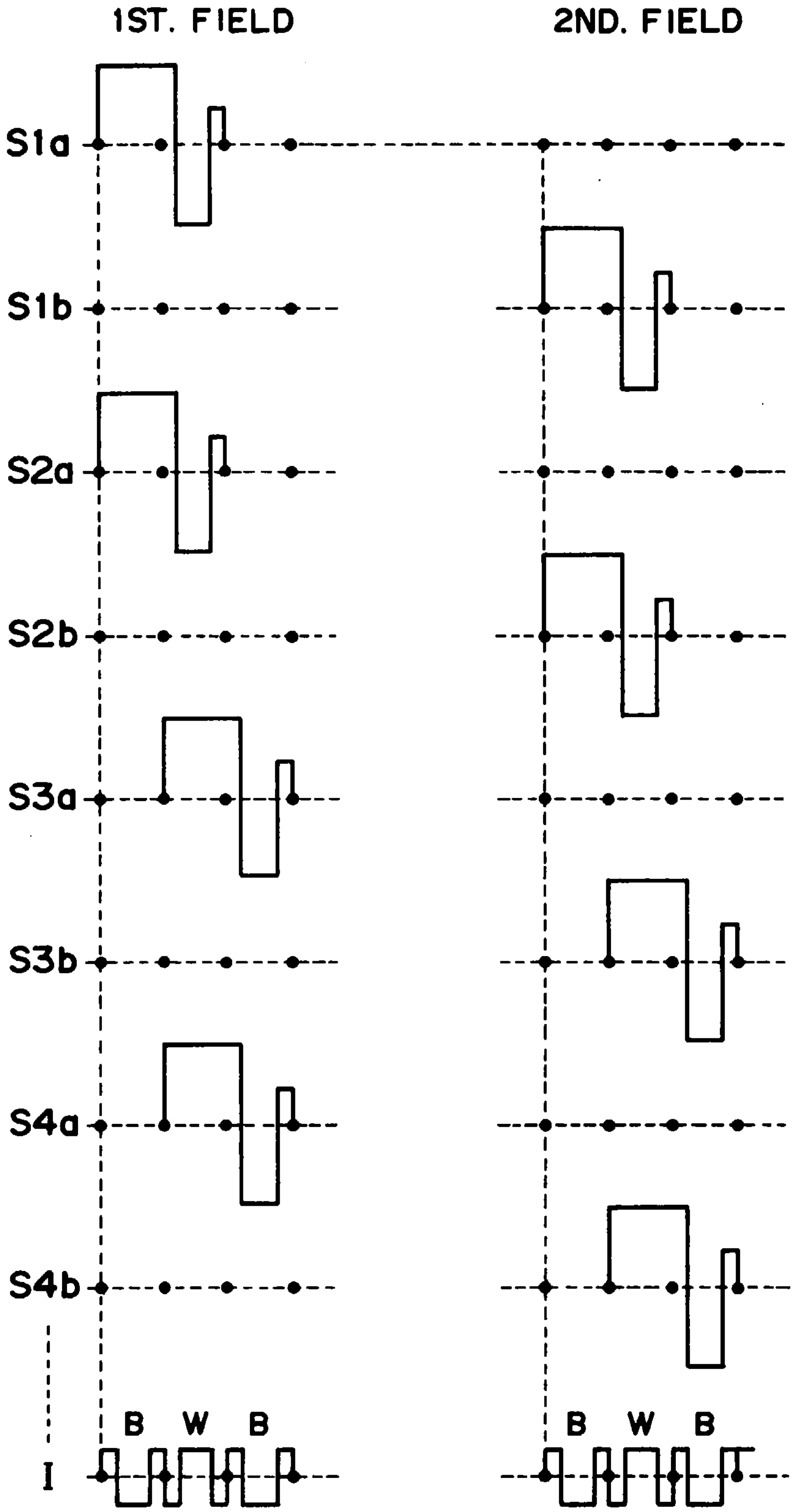


FIG. 5

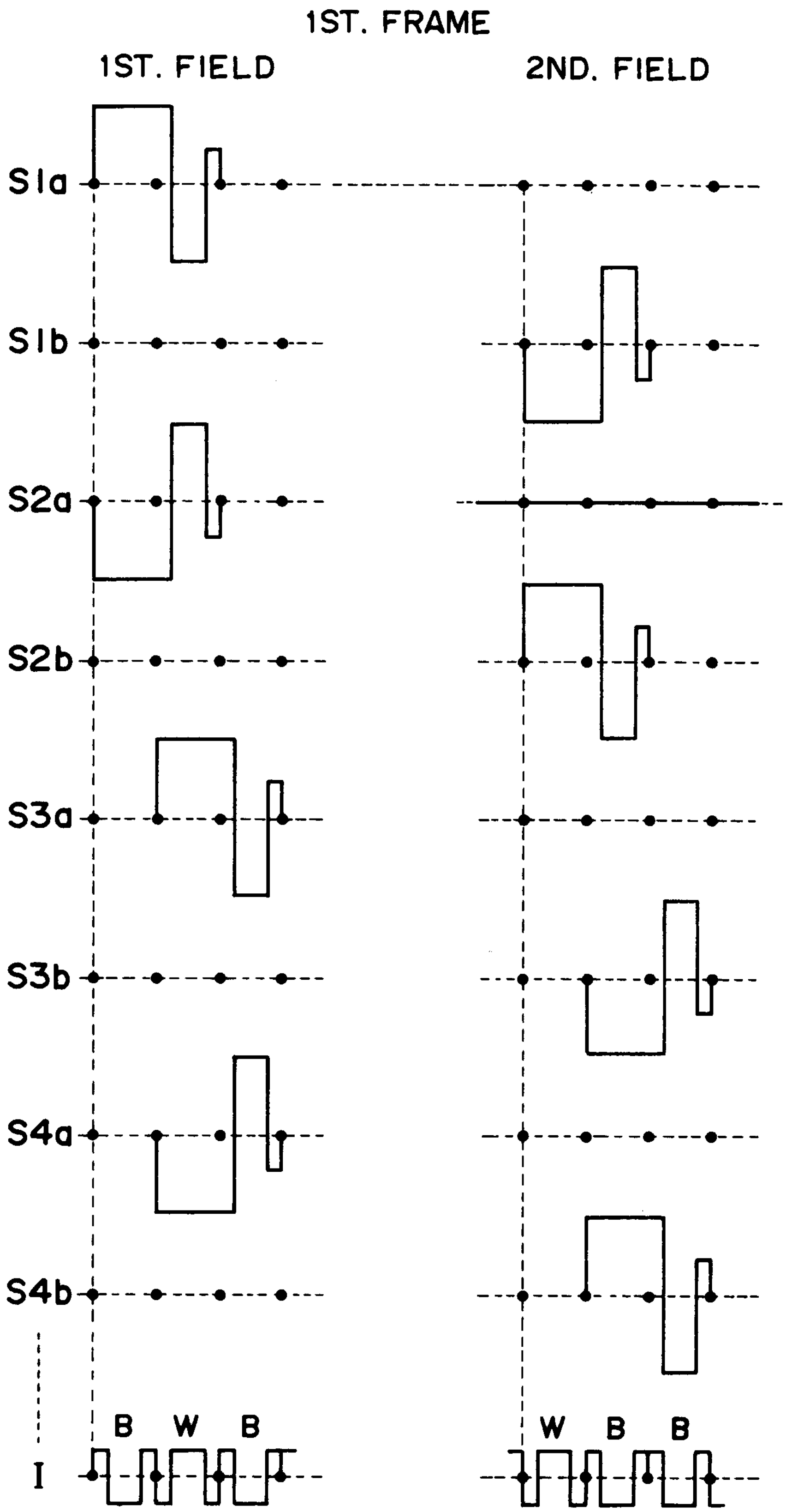

1ST. FRAME
1ST. FIELD
2ND. FIELD
S1a
S1b
S2a
S2b
S3a
S3b
S4a
S4b
I
B
W
B
W
B
B

FIG. 6

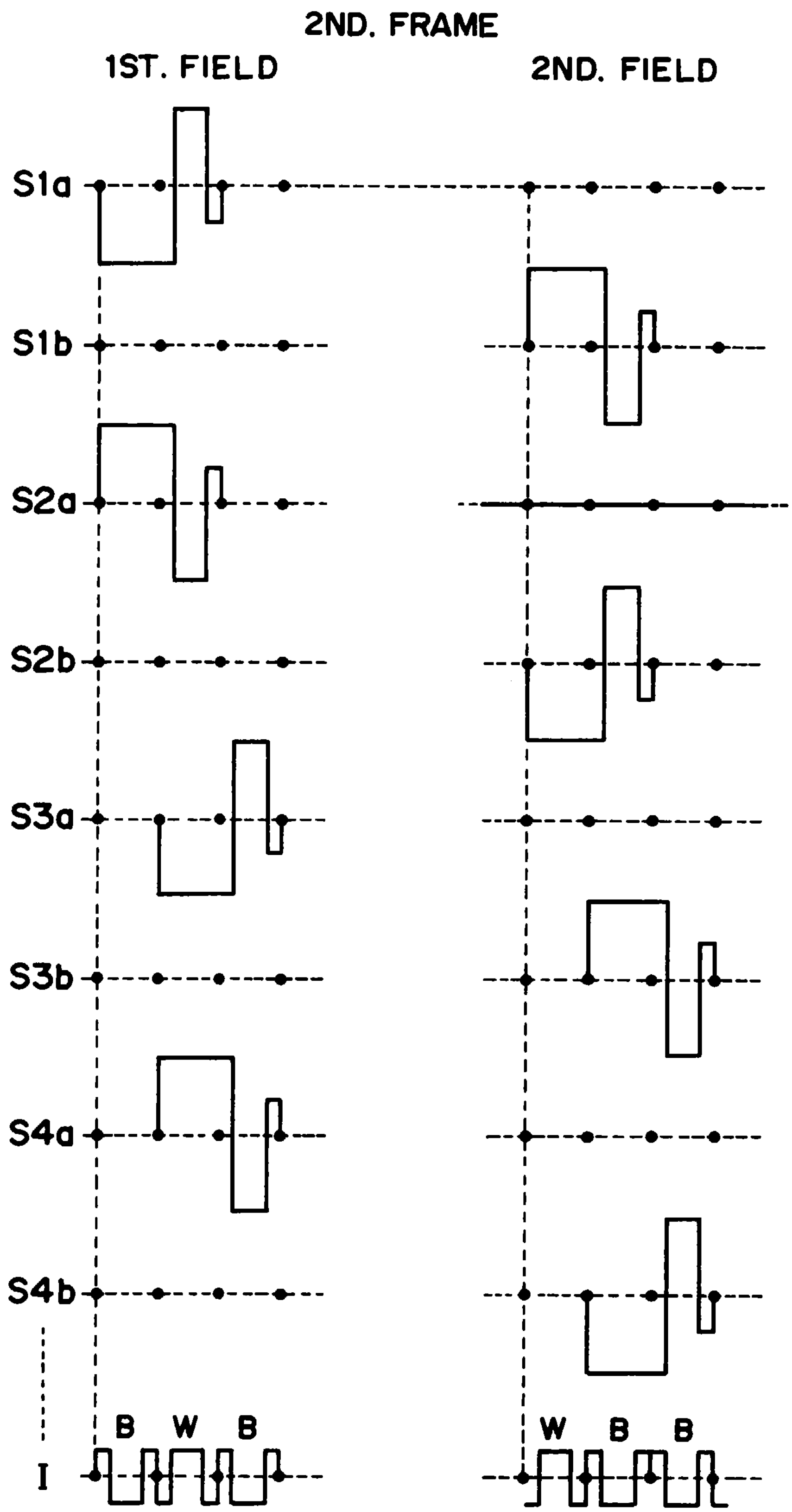

2ND. FRAME
1ST. FIELD
2ND. FIELD
S1a
S1b
S2a
S2b
S3a
S3b
S4a
S4b
I
B W B
W B B

FIG. 7

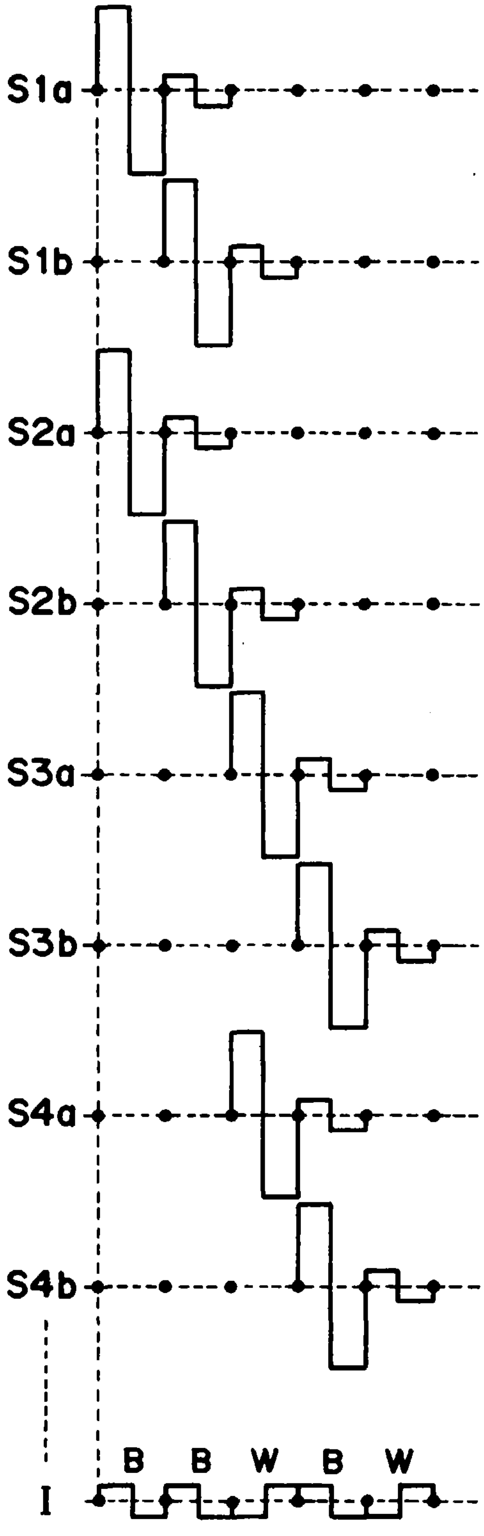


FIG. 8

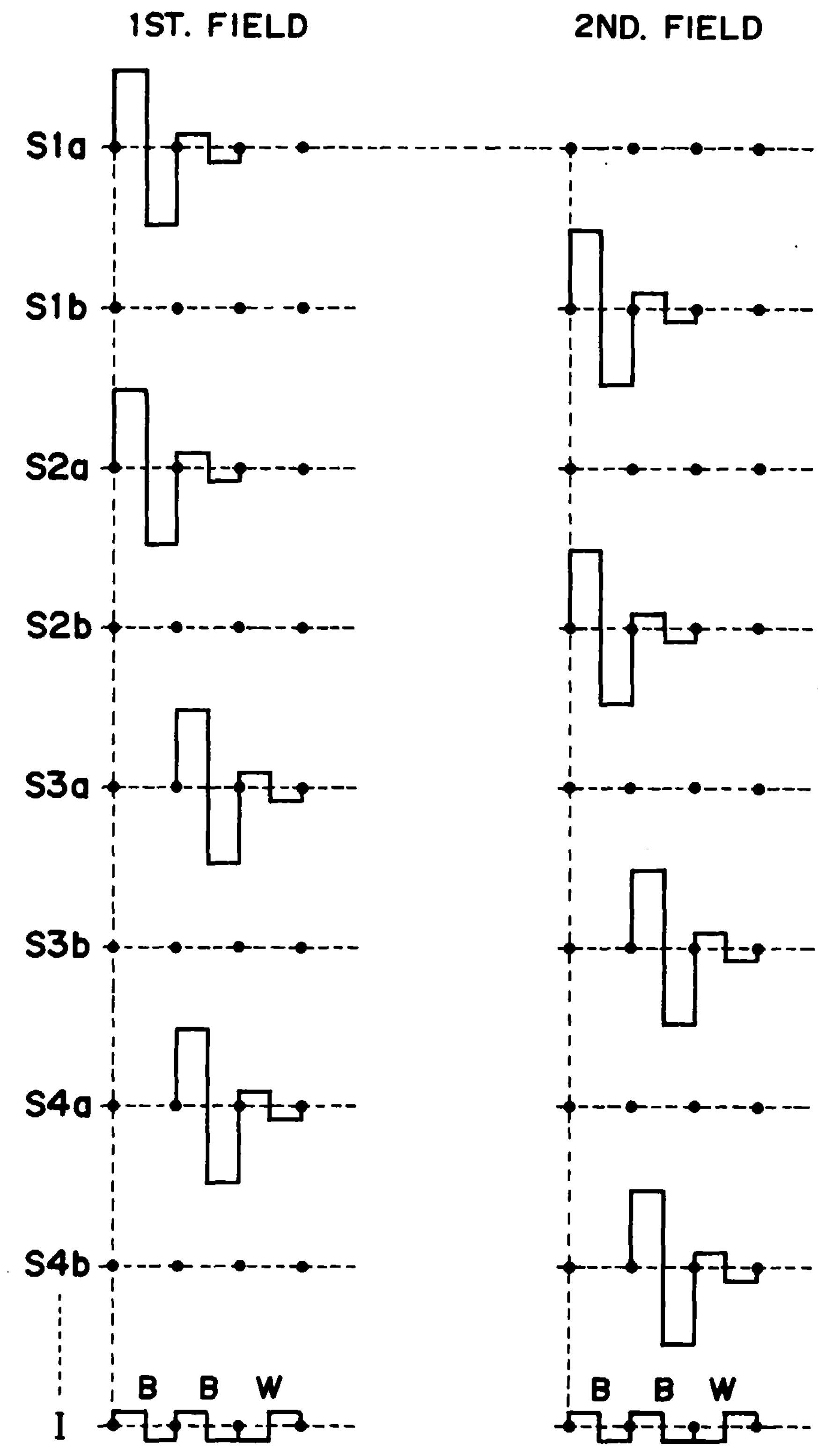


FIG. 9

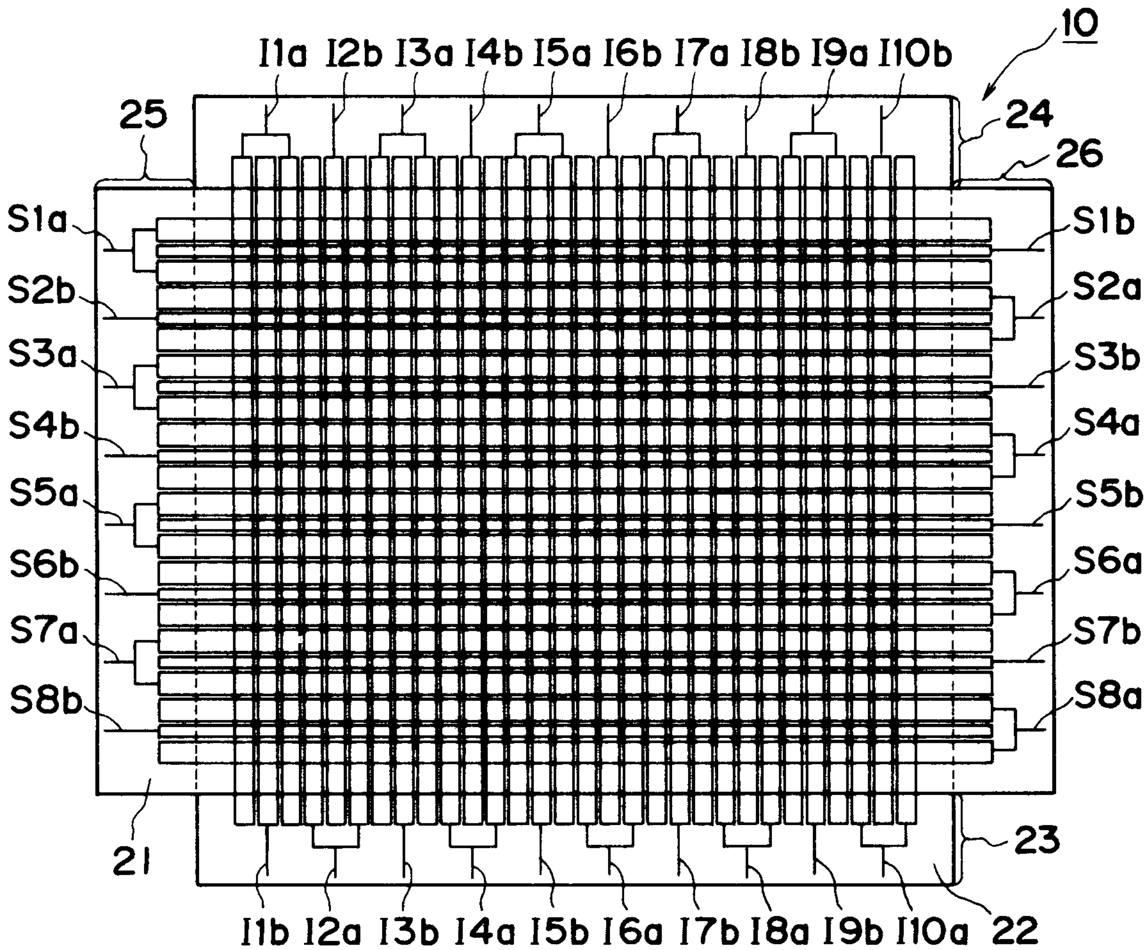
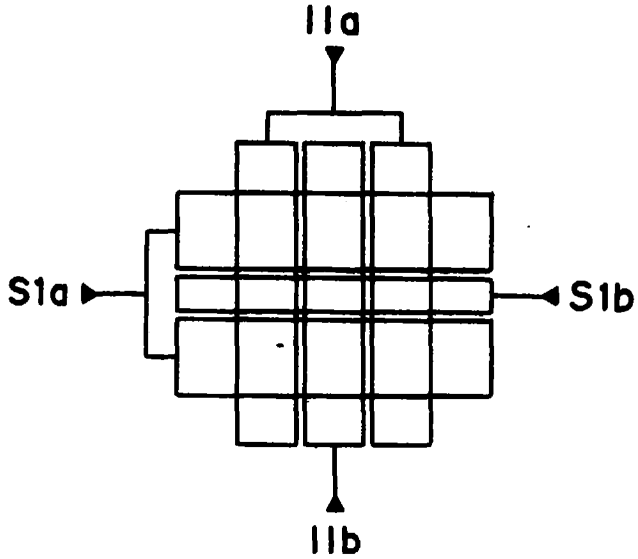
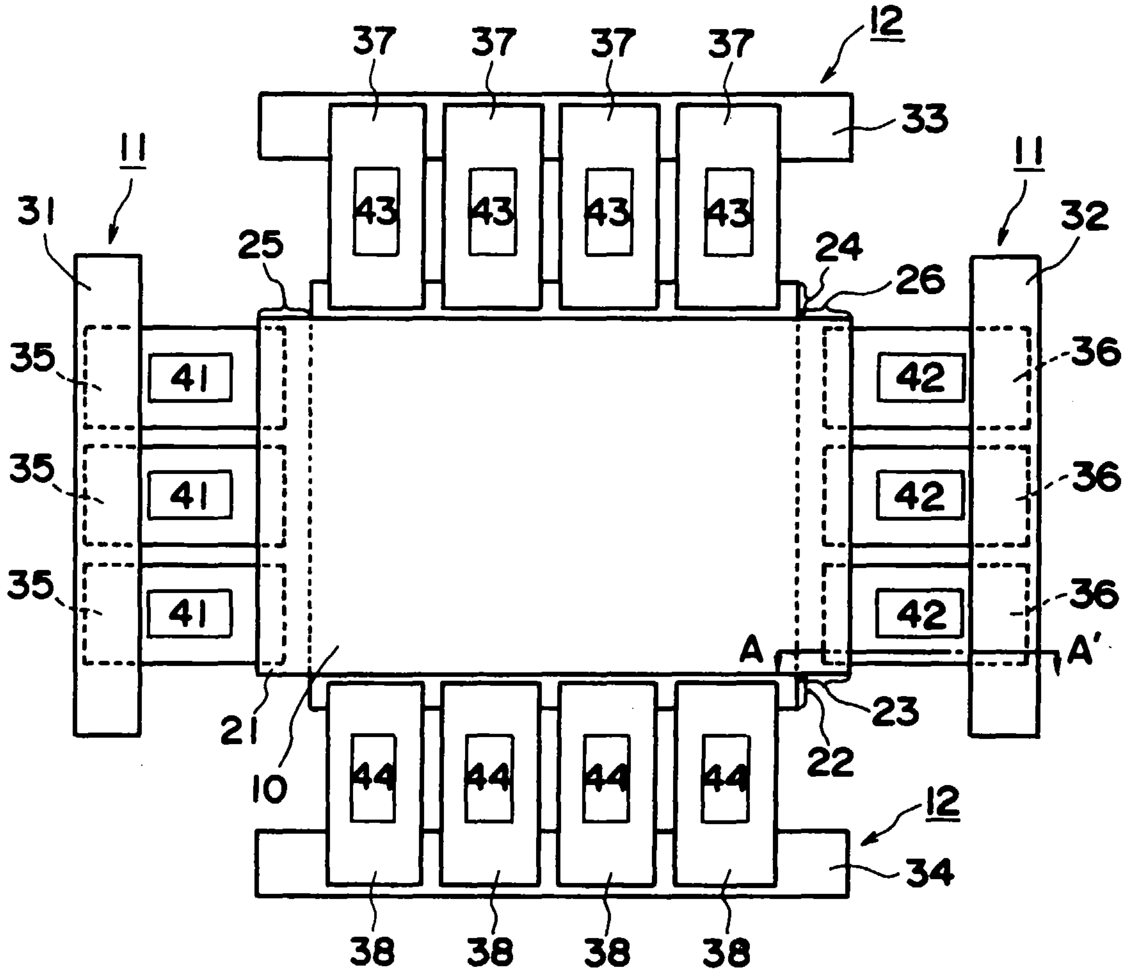

10
I1a
I2b
I3a
I4b
I5a
I6b
I7a
I8b
I9a
I10b
25
24
26
S1a
S2b
S3a
S4b
S5a
S6b
S7a
S8b
S1b
S2a
S3b
S4a
S5b
S6a
S7b
S8a
21
23
22
I1b
I2a
I3b
I4a
I5b
I6a
I7b
I8a
I9b
I10a

FIG. 10



11a
S1a
S1b
11b

FIG. 11



37
37
37
37
12
33
11
11
31
32
43
43
43
43
25
24
26
35
41
42
36
35
41
42
36
35
41
42
36
A
A'
21
23
22
10
44
44
44
44
12
34
38
38
38
38

FIG. 12

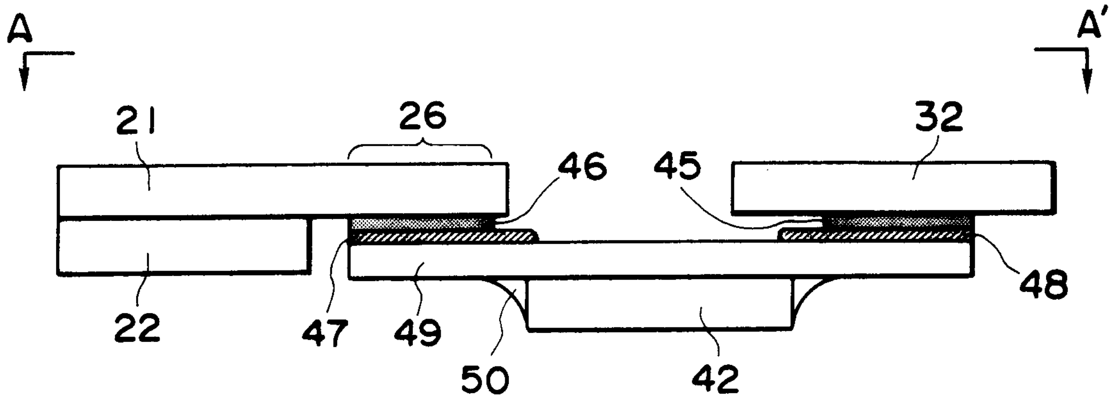


FIG. 13

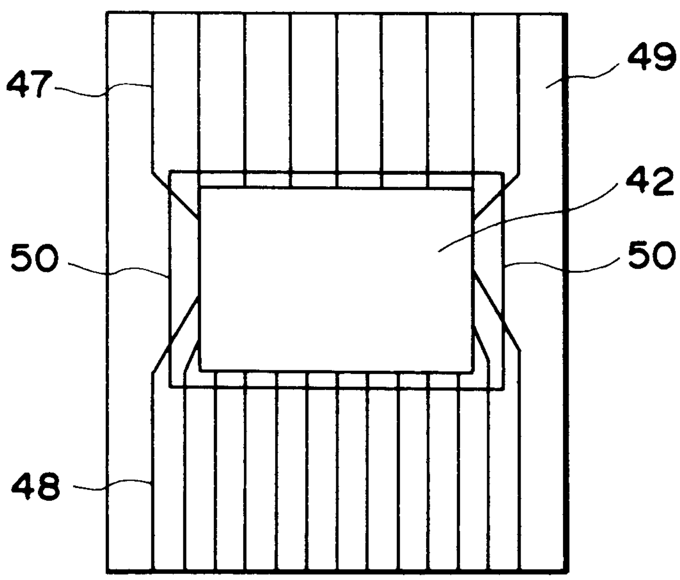


FIG. 14

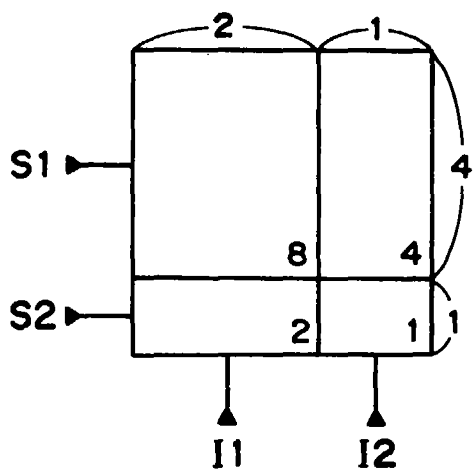


FIG. 15A

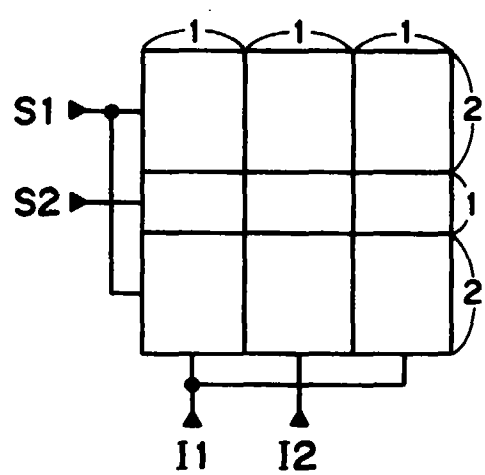


FIG. 15B

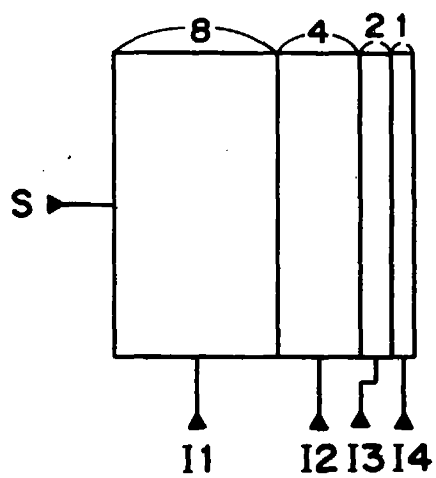


FIG. 15C

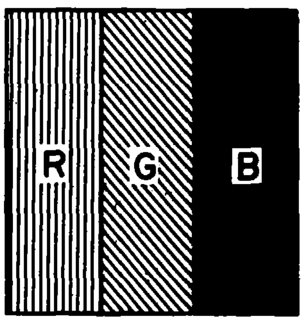
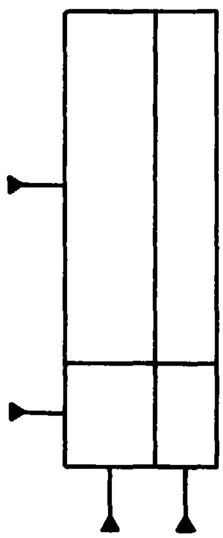
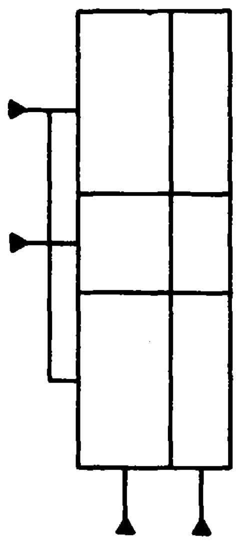


FIG. 16A





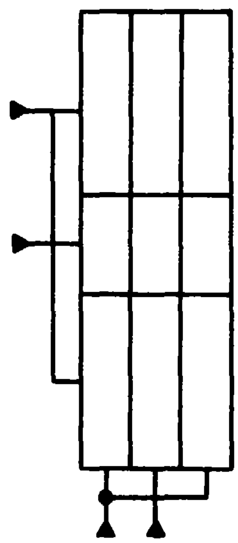


FIG. 16B FIG. 16C FIG. 16D

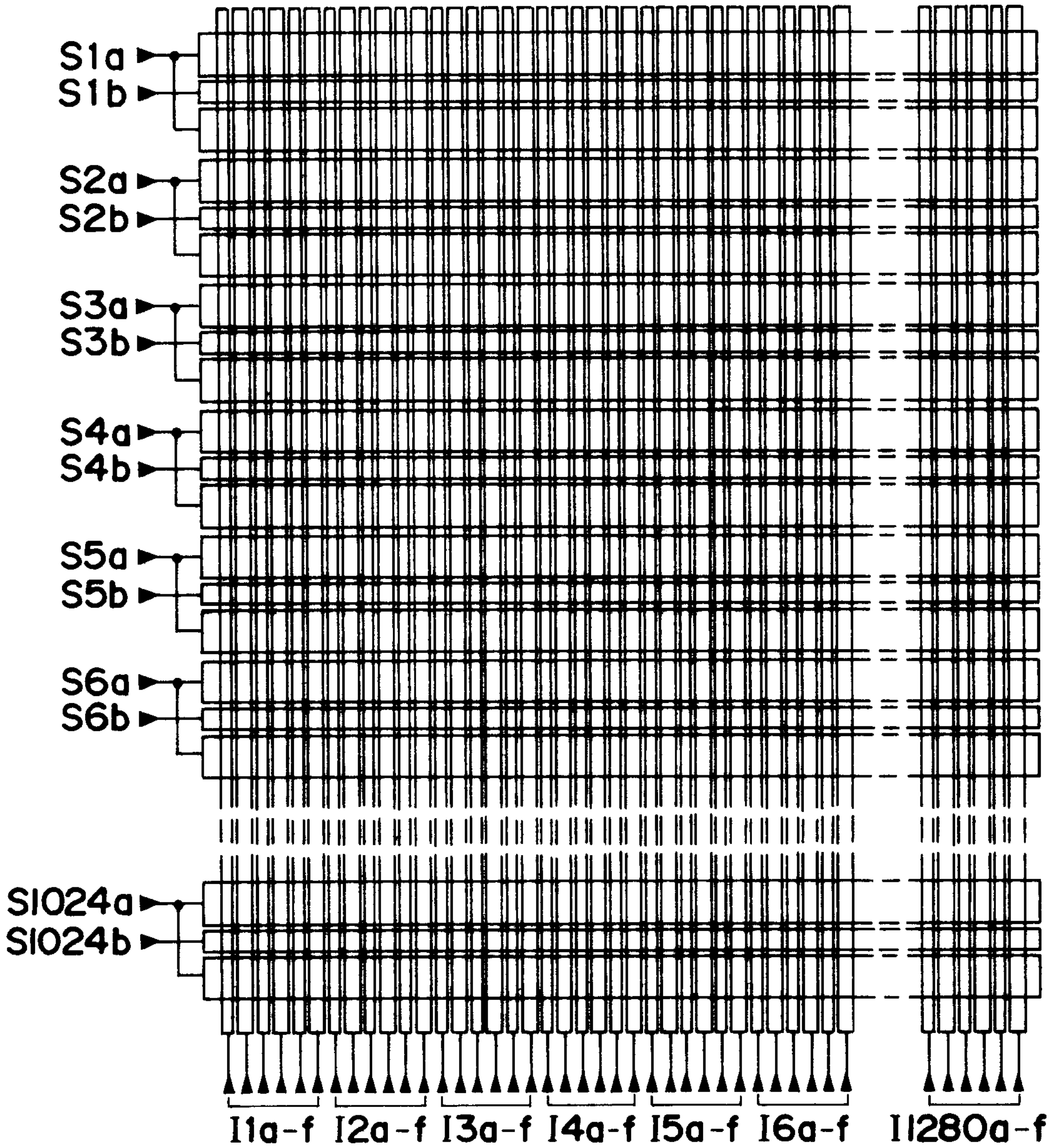

S1a
S1b
S2a
S2b
S3a
S3b
S4a
S4b
S5a
S5b
S6a
S6b
S1024a
S1024b
I1a-f
I2a-f
I3a-f
I4a-f
I5a-f
I6a-f
I1280a-f

FIG. 17

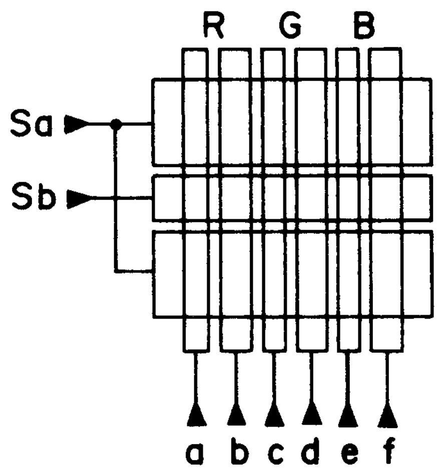

R
G
B
Sa
Sb
a
b
c
d
e
f

FIG. 18

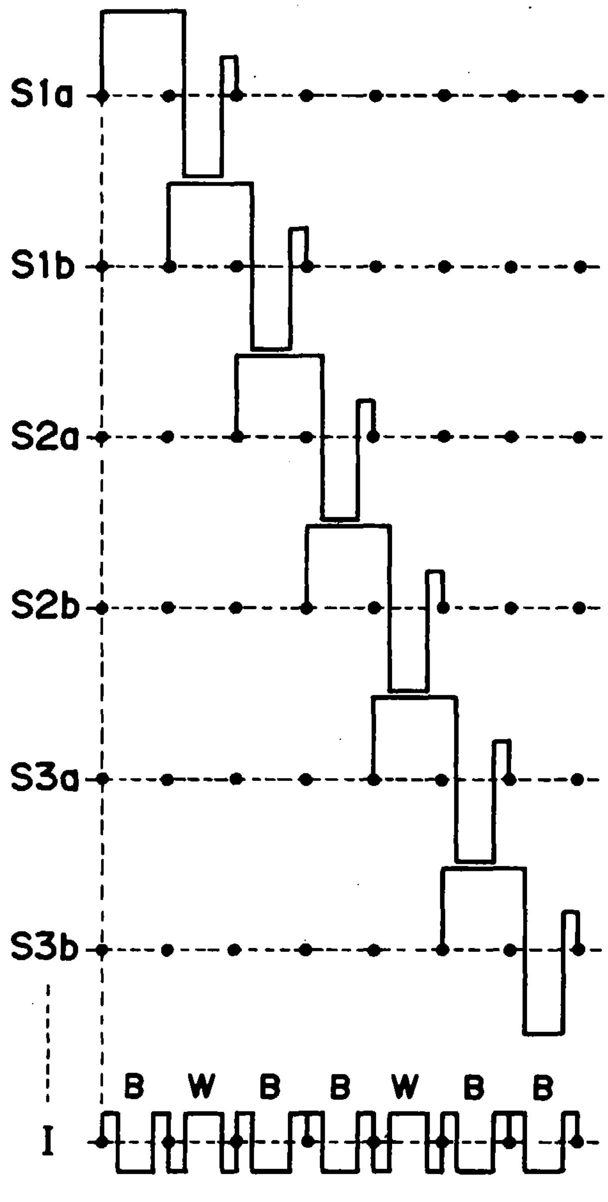


FIG. 19

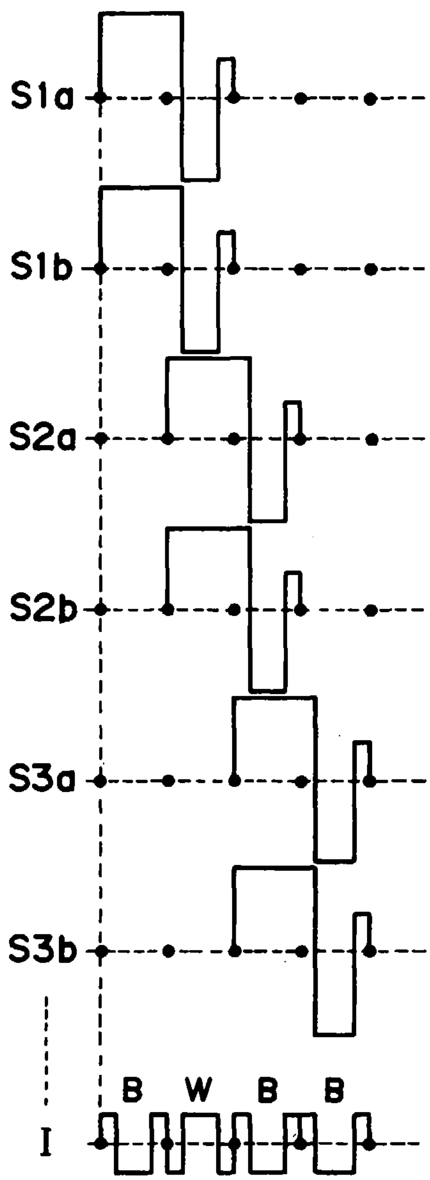
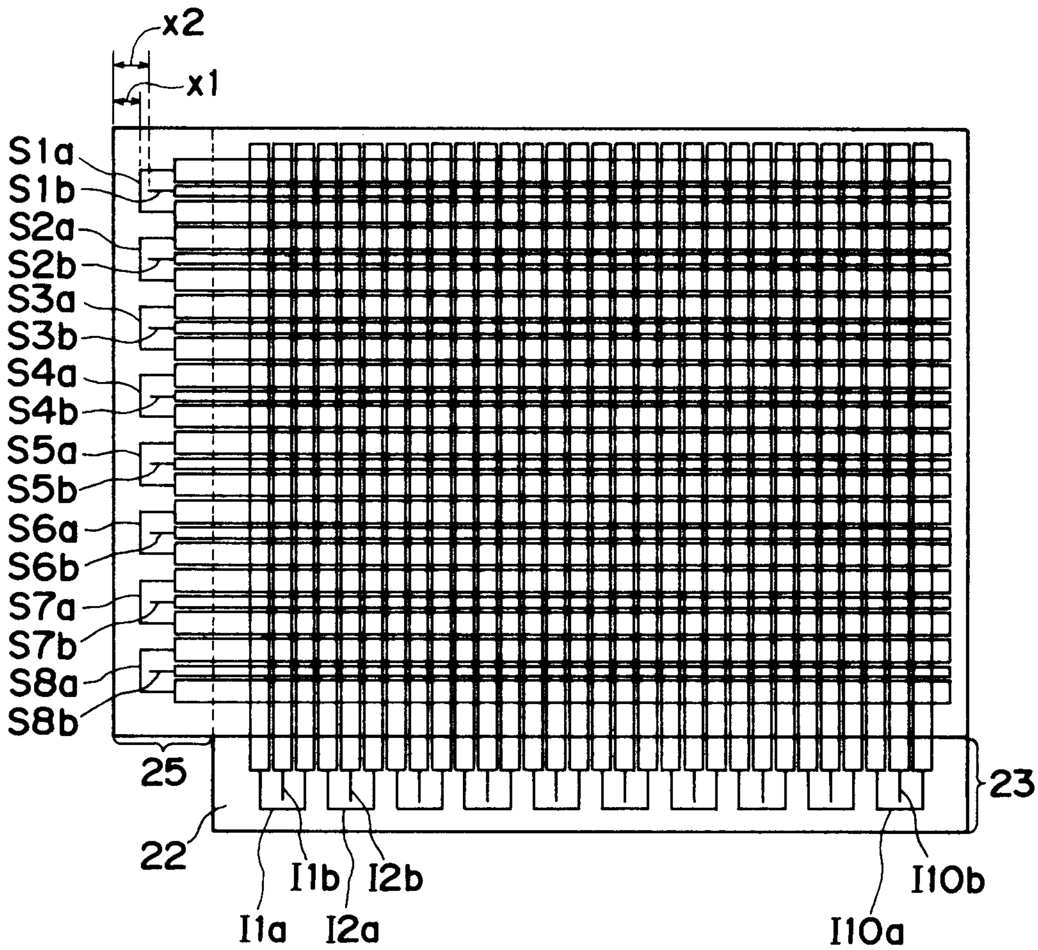


FIG. 20



x2
x1
S1a
S1b
S2a
S2b
S3a
S3b
S4a
S4b
S5a
S5b
S6a
S6b
S7a
S7b
S8a
S8b
25
23
22
I1b
I2b
I1a
I2a
I10b
I10a

FIG. 21