

FIELD SEQUENTIAL COLOR DISPLAY DEVICE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a field sequential color display device, particularly to a field sequential color display device conducting a color display by switching three primary color signals.

Description of Related Art

At present, a field sequential color display device has been reduced into practice as a color display device. An LCS (Liquid Crystal Shutter) system is used in the field sequential color display device. According to the LCS system, images in full color are provided by having a liquid crystal shutter comprising liquid crystal cells and color polarizers synchronize with switching timings and driving a CRT by field sequential image signals of red (R), blue (B) and green (G).

Meanwhile, according to a field sequential color display device using a liquid crystal shutter, color mixture (color shading) is caused between image fields by delays in response speeds of liquid crystal cells constituting the liquid crystal shutter. Fig. 7 is a diagram showing a response characteristic of a liquid crystal cell. The ordinate designates a relative luminance (%) and the abscissa designates time t (ms) whereby a response

characteristic curve Cs of a liquid cell is shown. It is known from the diagram that when a liquid crystal cell is switched from ON to OFF, the switching cannot be conducted immediately but 1 (ms) is required therefor.

Accordingly, even if color switching is conducted in a vertical blanking period, color is not switched completely in the time period and therefore, color shading is caused at the front head of an image signal of a next color.

Next, a detailed explanation will be given of color shading. Table 1 shows selection of color in accordance with ON/OFF of a drive signal of a liquid crystal cell.

Table 1

	R	B	G
Sd21	ON	ON	OFF
Sd22	OFF	ON	ON

R is selected when drive signals (Sd21, Sd22) for driving liquid crystal cells are (ON, OFF). B is selected when drive signals (Sd21, Sd22) are (ON, ON). G is selected when the drive signals (Sd21, Sd22) are (OFF, ON).

Fig. 8 is a diagram showing a behavior of switching timing causing color shading. In a field F21, responses of liquid crystal cells where both of the drive signals (Sd21, Sd22) are ON, are shown, by which an image of B is caused according to Table 3. Further, according to a field F22,

responses of liquid crystal cells where the drive signals (Sd21, Sd22) are (OFF, ON), are shown, by which an image of G is to be caused. However, according to the liquid crystal cell driven by the drive signal Sd21, a response in switching from ON to OFF is delayed by which a situation where both of the two sheets of liquid crystal cells are ON, is produced. Therefore, B is mixed in a field section 76 by which color shading is caused.

Similarly, in a field F23, responses of liquid crystal cells where the drive signals (Sd21, Sd22) are (ON, OFF), are shown, by which an image of R is to be caused. However, according to the liquid crystal cell driven by the drive signal Sd22; a response for switching from ON to OFF is delayed by which a situation where both of the two sheets of liquid crystal cells are ON, is produced. B is mixed also in a field section 77 by which color shading is caused.

With respect to such a problem, according to, for example, U.S.P. No. 4652087, it is proposed to divide an electrode of a liquid crystal cell by n pieces in a direction orthogonal to a face in correspondence with image regions. According to the proposal, shutter timings of the respective sub pieces of the electrode divided by n are successively shifted within a range of $1-1/n$ field by which they are switched prior to original timings.

However, according to the above-described conventional example, in a low temperature range of 10°C or

lower, the response speed of a liquid crystal cell is further delayed and exceeds a correction range by which color shading is caused within a boundary of an electrode dividing line.

Further, in order to divide the electrode of a liquid crystal cell, a large-scaled fabrication device such as a laser beam machining device, a photolithography etching device or the like is needed.

Furthermore, product cost is considerably increased since drive elements and the like in accordance with a number of division of an electrode are needed.

The present invention has been carried out in view of such a point and it is an object of the present invention to provide a field sequential color display device capable of displaying full color images having a high degree of color purity with no color shading without dividing an electrode of a liquid crystal cell constituting a liquid crystal shutter.

SUMMARY OF THE INVENTION

In order to solve the above-described problem according to an aspect of the present invention, there is provided a field sequential color display device conducting a color display by switching three primary color signals, the device including a monochromatic CRT (Cathode Ray Tube) for displaying images where luminances thereof are varied,

sequential color signal forming means for forming sequential color signals for driving the monochromatic CRT from the three primary color signals, a liquid crystal shutter comprising a plurality of color polarizers arranged in series on an optical axis in respect of the monochromatic CRT and a plurality of liquid crystal cells arranged in series on the optical axis between the plurality of color polarizers, and polarization direction controlling means for controlling polarization directions of color beams such that a light transmittance of the liquid crystal shutter is minimized when two sheets or more of the liquid crystal cells are simultaneously turned on by driving polarization axes of the liquid crystal cells.

Here, the sequential color signal forming means forms the sequential color signals for driving the monochromatic CRT from the three primary color signals. The liquid crystal shutter is constituted by the plurality of color polarizers arranged in series on the optical axis in respect of the monochromatic CRT and the plurality of liquid crystal cells arranged in series on the optical axis between the color polarizers. The polarization direction controlling means controls the polarization directions of the color beams such that the light transmittance of the liquid crystal shutter is minimized when two sheets or more of the liquid crystal cells are simultaneously turned on by driving the polarization axes of the liquid crystal cells.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a principle diagram of a field sequential color display device according to the present invention;

Fig. 2 is a view showing the constitutions of a monochromatic CRT and a liquid crystal shutter;

Fig. 3 is a diagram showing switching timings for preventing color shading;

Fig. 4 is a view showing a color switching operation of a liquid crystal shutter including two sheets of liquid crystal cells;

Fig. 5 is a diagram showing switching timings for preventing color shading;

Fig. 6 is a view showing a color switching operation of a liquid crystal shutter including three sheets of liquid crystal cells;

Fig. 7 is a diagram showing a response characteristic of a liquid crystal cell; and

Fig. 8 is a diagram showing switching timings causing color shading.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An explanation will be given of embodiments of the present invention in reference to the drawings as follows. Fig. 1 is a principle diagram of a field sequential color display device. The field sequential color display device is constituted by a monochromatic CRT 4, sequential color

signal forming means 5 for forming sequential color signals, a liquid crystal shutter 30 including color polarizers 11 and 13, a neutral polarizer 12 and liquid crystal cells 21 and 22, and polarization direction controlling means 6 for controlling polarization directions of color beams by driving the liquid crystal cells 21 and 22.

Next, an explanation will be given of operations of respective means. The sequential color signal forming means 5 conducts the γ correction on R, G and B after matrix transformation, compresses a time axis and forms sequential color signals in synchronism with field synchronizing signals. Further, the monochromatic CRT 4 is driven by the sequential color signals. That is, the monochromatic CRT 4 displays images with luminance variation in correspondence with respective changes in levels of the sequential color signals.

The liquid crystal shutter 30 is constituted by the color polarizers 11 and 13, the neutral polarizer 12 and the liquid crystal cells 21 and 22 arranged in series on the optical axis of the monochromatic CRT 4. Each of the color polarizers 11 and 13 and the neutral polarizer 12 is provided with a horizontal polarization axis and a vertical polarization axis by which set color beams are selectively transmitted. The liquid cells 21 and 22 polarize color beams. Details thereof will be mentioned later.

The polarization direction controlling means 6 controls the polarization directions of the color beams such that the light transmittance of the liquid crystal shutter 30 is minimized when the liquid crystal cells 21 and 22 are simultaneously turned on by driving the polarization axes of the liquid crystal cells 21 and 22. Here, the minimum transmitting light constitutes BLACK in view of color.

As a specific control of the polarization direction, the polarization axes of the liquid crystal cells 21 and 22 are driven by voltage levels of drive signals Sd1 and Sd2 in synchronism with the field synchronizing signals. When the drive signal is ON, the polarization axes of the liquid crystal cell are not driven and the color beams are transmitted as they are with no polarization. Further, when the drive signal is OFF, the polarization axes of the liquid crystal cell are rotated by 90° and the color beams are transmitted after being subjected to polarization.

Next, an explanation will be given of an outline of a field sequential color display device in an LCS system. Fig. 2 is a diagram showing the constitution examples of the monochromatic CRT and the liquid crystal shutter. The monochromatic CRT 4 that is a source of generating images, is driven by image signals of the three primary colors which are sent field-sequentially.

Further, the liquid crystal shutter 30 including two sheets of the color polarizers 11 and 13, two sheets of the

liquid crystal cells 21 and 22 and one sheet of the neutral polarizer 12 is installed at the front face of the monochromatic CRT 4. The liquid crystal cells 21 and 22 are liquid crystal cells with high-speed response which are turned ON/OFF by the drive signals Sd1 and Sd2 from the polarization direction controlling means. Color selection in synchronism with the image signals of the three primary colors is carried out by the liquid crystal shutter 30.

Next, an explanation will be given of color selection when color beams are transmitted through the color polarizers 11 and 13 and the neutral polarizer 12. The horizontal polarization axis Cy (G, B) of the color polarizer 11 that is the nearest to a screen of the monochromatic CRT 4 allows to transmit selectively G, B and Cy (cyan) which is a color beam synthesized by G and B. Also, the vertical polarization axis R allows to transmit selectively a color beam of R.

Meanwhile, according to the neutral polarizer 12 opposed to the color polarizer 11 via the liquid crystal cell 21, the horizontal polarization axis O (BLACK) is a light absorbing axis and therefore, a beam transmitting therethrough becomes BLACK. Also, the vertical polarization axis R (R, G, B) allows to transmit R, G, B and W (white) that is a color beam synthesized thereby.

Further, according to the color polarizer 13 opposed to the neutral polarizer 12 via the liquid cell 22, the

horizontal axis YL (R, G) allows to transmit selectively R, G and YL (yellow) that is a color beam synthesized by R and G. Also, the vertical polarization axis B allows to transmit selectively a color beam of B.

Next, an explanation will be given of an optical operation of the liquid crystal shutter when the present invention is applied. Table 2 shows color selection in accordance with ON/OFF of the drive signals of the liquid crystal cells when the present invention is applied.

Table 2

	R	B	G	BLACK
Sd1	ON	OFF	OFF	ON
Sd2	OFF	ON	OFF	ON

R is selected when the drive signals (Sd1, Sd2) are (ON, OFF). B is selected when the drive signals (Sd1, Sd2) are (OFF, ON). G is selected when the drive signals (Sd1, Sd2) are (OFF, OFF). Also, the polarization direction controlling means controls to select BLACK when the drive signals (Sd1, Sd2) are (ON, ON).

Fig. 3 is a diagram showing switching timings preventing color shading. In a field F1, responses of the liquid crystal cells when the drive signals (Sd1, Sd2) are (ON, OFF), are shown, by which an image of R is generated by a combination of color selection indicated by Table 2. Further, in a field F2, responses of the liquid crystal

cells when the drive signals (Sd1, Sd2) are (OFF, ON), are shown. According to the conventional example, the response of the liquid crystal cell in correspondence with the drive signal Sd1 in switching from ON to OFF is delayed and therefore, both of the two sheets of the liquid crystal cells are ON by which color shading is caused in the field section. However, according to the embodiment, when both of the drive signals (Sd1, Sd2) are (ON, ON), the color selection is controlled to constitute BLACK and therefore, color shading is not caused in a field section 71.

Further, in a field F3, responses of the liquid crystal cells when both of the drive signals (Sd1, Sd2) are (OFF, OFF), are shown. According to the conventional example, the response of the liquid crystal cell in correspondence with the drive signal Sd2 in switching from ON to OFF is delayed and accordingly, the two sheets of the liquid crystal cells are (OFF, ON) by which color shading is caused in the field section. However, B is caused in a field section 72 by a combination of color selection indicated by Table 2 when the drive signals (Sd1, Sd2) are (OFF, ON). Therefore, in this case no color shading is caused visually since G and B are near to each other.

Fig. 4 is a view showing color switching operation of the liquid crystal shutter including two sheets of the liquid crystal cells. The liquid crystal shutter is constituted by the two sheets of the liquid crystal cells

and the two sheets of the color polarizers 11 and 13 and the one sheet of the neutral polarizer 12. The liquid cell driven by the drive signal Sd1 is constituted by a liquid crystal cell 21a forming an ON state and a liquid crystal cell 21b forming an OFF state. Also, the liquid crystal cell driven by the drive signal Sd2, is constituted by a liquid crystal cell 22a forming an ON state and a liquid crystal cell 22b forming an OFF state.

Here, when each of the liquid crystal cells is brought into the ON state by the drive signal Sd1 or Sd2, the polarization direction is not changed. Further, when they are in the OFF state, the polarization direction is rotated by 90° .

For example, when the monochromatic CRT is driven by a BLACK signal, both of the two sheets of the liquid cells are brought into the ON state. The respective axes of the color polarizer 11 are the horizontal polarization axis Cy (G, B) and the vertical polarization axis R and therefore, with respect to an incident beam W, G and B are allowed to transmit in the horizontal direction and R is allowed to transmit in the vertical direction. Further, the polarization direction is not changed by the liquid crystal cell 21a in the ON state and therefore, the color beams which have transmitted through the color polarizer 11 are transmitted through the liquid crystal cell 21a as they are. Further, the color beams are cut by the horizontal

polarization axis O (BLACK) of the neutral polarizer 12 and only R that is common to the vertical polarization axis W (R, G, B) is allowed to transmit through the neutral polarizer 12.

Further, R is allowed to transmit through the liquid crystal cell 22a as it is since the polarization direction is not changed by the next stage of the liquid crystal cell 22a in the ON state. The vertical polarization axis B of the color polarizer 13 allows only B to transmit therethrough and therefore, R is cut and finally the color beam becomes BLACK.

When the monochromatic CRT is driven by an R signal, the liquid crystal cell 21a is brought into the ON state and the liquid crystal cell 22b is brought into the OFF state. The respective axes of the color polarizer 11 are the horizontal polarization axis Cy (G, B) and the vertical polarization axis R and therefore, in respect of the incident beam W, G and B are allowed to transmit in the horizontal direction and R is allowed to transmit in the vertical direction. Further, the polarization direction is not changed by the liquid crystal cell 21a in the ON state and therefore, the color beams which have transmitted through the color polarizer 11, are allowed to transmit through the liquid crystal cell 21a as they are. The color beams are cut by the horizontal polarization axis O (BLACK) of the neutral polarizer 12 and only R that is common to the

vertical polarization axis W (R, G, B) is allowed to transmit through the neutral polarizer 12. Next, the polarization direction is changed by 90° by the next stage of the liquid crystal cell 22b in the OFF state and therefore, R is rotated by 90° by the liquid crystal cell 22b and allowed to transmit therethrough. The horizontal optical axis YL (R, G) of the color polarizer 13 allows R and G to transmit therethrough and therefore, the color beam finally becomes R since G has been cut.

When the monochromatic CRT is driven by a B signal, the liquid crystal cell 21b is brought into the OFF state and the liquid crystal cell 22a is brought into the ON state. The respective axes of the color polarizer 11 are the horizontal polarization axis Cy (G, B) and the vertical polarization axis R and accordingly, with respect to the incident light W, G and B are allowed to transmit through in the horizontal direction and R is allowed to transmit in the vertical direction. The polarization direction is changed by 90° by the liquid crystal cell 21b in the OFF state and therefore, the color beams which have transmitted through the color polarizer 11, are rotated by 90° by the liquid crystal cell 21b and allowed to transmit therethrough. The color beam is cut by the horizontal polarization axis O (BLACK) of the neutral polarizer 12 and G and B that are common to the vertical polarization axis W (R, G, B) are allowed to pass through the neutral polarizer 12.

The polarization direction is not changed by the next stage of the liquid crystal cell 22a in the ON state and therefore, G and B are allowed to transmit through the liquid crystal cell 22a as they are. Further, the vertical polarization axis B of the color polarizer 13 allows only B to transmit therethrough and accordingly, the color beam finally becomes B.

When the monochromatic CRT is driven by a G signal, both of the liquid crystal cells 21b and 22b are brought into the OFF state. The respective axes of the color polarizer 11 are the horizontal polarization axis Cy (G, B) and the vertical polarization axis R and accordingly, with respect to the incident beam W, G and B are allowed to transmit in the horizontal direction and R is allowed to transmit in the vertical direction. The polarization direction is changed by 90° by the liquid crystal cell 21b in the OFF state and therefore, the color beams which have transmitted through the color polarizer 11, are rotated by 90° by the liquid crystal cell 21b and are allowed to transmit therethrough. Further, the color beam is cut by the horizontal polarization axis O (BLACK) of the neutral polarizer 12 and G and B which are common to the vertical polarization axis W (R, G, B) are allowed to transmit through the neutral polarizer 12.

The polarization direction is changed by 90° by the next stage of the liquid crystal cell 22b in the OFF state

and accordingly, G and B are rotated by 90° by the liquid crystal cell 22b and are allowed to transmit therethrough. The horizontal polarization axis YL (R, G) of the color polarizer 13 allows R and G to transmit therethrough and therefore, the color beam finally becomes G since R has been cut.

Next, an explanation will be given of a second embodiment of the present invention. The second embodiment uses a liquid crystal shutter constituted by three sheets of liquid crystal cells and four sheets of color polarizers. Table 3 indicates color selection accompanied by ON/OFF of drive signals of the liquid crystal cells.

Table 3

	R	B	G	BLACK
Sd11	ON	OFF	OFF	ON ON OFF ON
Sd12	OFF	ON	OFF	ON OFF ON ON
Sd13	OFF	OFF	ON	OFF ON ON ON

R is selected when drive signals (Sd11, Sd12, Sd13) are (ON, OFF, OFF). B is selected when the drive signals (Sd11, Sd12, Sd13) are (OFF, ON, OFF). G is selected when the drive signals (Sd11, Sd12, Sd13) are (OFF, OFF, ON). Further, the polarization direction controlling means controls to select BLACK when the drive signals (Sd11, Sd12, Sd13) are (ON, ON, OFF), or (ON, OFF, ON), or (OFF, ON, ON),

or (ON, ON, ON).

Fig. 5 is a diagram showing switching timings preventing color shading. In a field F11, responses of the liquid crystal cells when the drive signals (Sd11, Sd12, Sd13) are (ON, OFF, OFF), are shown. According to the conventional example, the response of the liquid crystal cell corresponding to the drive signal Sd13 in switching from ON to OFF is delayed and therefore, both of the two sheets of the liquid crystal cells corresponding to the drive signals Sd11 and Sd13 are brought into the ON state and color shading is caused in the field section. However, according to the embodiment, color shading is not caused in a field section 73 since color selection is controlled to constitute BLACK when the drive signals are (ON, OFF, ON).

Further, in a field F12, responses of the liquid crystal cells when the drive signals (Sd11, Sd12, Sd13) are (OFF, ON, OFF), are shown. According to the conventional example, the response of the liquid crystal cell in correspondence with the drive signal Sd11 in switching from ON to OFF is delayed and accordingly, both of the two sheets of the liquid crystal cells corresponding to the drive signals Sd11 and Sd12 are brought into the ON state by which color shading is caused in the field section. However, according to the present invention, when the drive signals are (ON, ON, OFF), color selection is controlled to constitute BLACK and accordingly, color shading is not

caused in a field section 74.

Furthermore, in a field F13, responses of the liquid crystal cells when the drive signals (Sd11, Sd12, Sd13) are (OFF, OFF, ON), are shown. According to the conventional example, the response of the liquid crystal cell in correspondence with the drive signal Sd12 in switching from ON to OFF is delayed and therefore, both of the two sheets of the liquid crystal cells corresponding to the drive signals Sd12 and Sd13 are brought into the ON state by which color shading is caused in the field section. However, according to the present invention, when the drive signals are (OFF, ON, ON), color selection is controlled to constitute BLACK and accordingly, the color shading is not caused in a field section 75.

As has been explained, according to the second embodiment, in respect of the field sections causing color shading, the polarization directions of the liquid crystal cells are controlled such that BLACK minimizing the light transmittance is selectively outputted. Thereby, color shading among the image fields caused by the delays in the response speeds of the liquid crystal cells, can be prevented.

According to the first embodiment, there are provided the field sections where the color shading is not visually caused by considering combinations of color selection. Meanwhile, according to the second embodiment, by increasing

the numbers of sheets of the liquid crystal cells and the neutral polarizers, all of the states caused immediately after switching can be set to BLACK. Therefore, the combinations of color selection may not be considered and no color shading is caused.

Fig. 6 is a view showing a color switching operation of a liquid crystal shutter including three sheets of liquid crystal cells. According to the liquid crystal shutter of the second embodiment, the numbers of sheets of liquid crystal cells and neutral polarizers are more than those in the liquid crystal shutter of the first embodiment shown by Fig. 4.

The liquid crystal shutter according to the second embodiment is constituted by three sheets of liquid crystal cells, two sheets of color polarizers 15 and 16 and two sheets of neutral polarizers 14 and 17. The liquid crystal cell driven by the drive signal Sd11 is constituted by a liquid crystal cell 23a forming an ON state and a liquid crystal cell 23b forming an OFF state. The liquid crystal cell driven by the drive signals Sd12 is constituted by a liquid crystal cell 24a forming the ON state and a liquid crystal cell 24b forming the OFF state. The liquid crystal cell driven by the drive signal Sd13 is constituted by a liquid crystal cell 25a forming the ON state and a liquid crystal cell 25b forming the OFF state.

Here, when the liquid crystal cells are brought into

the ON state by the drive signals Sd11, Sd12 and Sd13, the polarization direction is not changed. Further, when they are brought into the OFF state, the polarization direction is rotated by 90° .

For example, when the monochromatic CRT is driven by the BLACK signal, all of the liquid crystal cells 23a, 24a and 25a are brought into the ON state. The respective axes of the neutral polarizer 14 are the horizontal polarization axis O (BLACK) and the vertical polarization axis W (R, G, B) and therefore, the incident beam W is transmitted in the vertical direction. The polarization direction is not changed by the liquid crystal cell 23a in the ON state and therefore, the color beams which have transmitted through the neutral polarizer 14 are allowed to transmit through the liquid crystal cell 23a as they are. Further, only R that is the color beam common to the vertical polarization axis R of the color polarizer 15, is allowed to transmit through the color polarizer 15.

The polarization direction is not changed by the next stage of the liquid style 24a in the ON state and therefore, R is allowed to transmit through the liquid crystal cell 24a as it is. There is no color beam common to the color polarizer 16 and accordingly, the color beam becomes BLACK. Therefore, the color beam is BLACK even after transmitting through the liquid crystal cell 25a and the neutral polarizer 17.

When the monochromatic CRT is driven by the R signal, the liquid crystal cell 23a is brought into the ON state, the liquid crystal cell 24b is brought into the OFF state and the liquid crystal cell 25b is brought into the OFF state. The respective axes of the neutral polarizer 14 are the horizontal polarization axis O (BLACK) and the vertical polarization axis W (R, G, B) and accordingly, the incident light W is allowed to transmit in the vertical direction. The polarization direction is not changed by the liquid crystal cell 23a in the ON state and therefore, the color beams which have transmitted through the neutral polarizer 14 are allowed to pass through the liquid crystal cell 23a as they are. And only R that is common to the vertical polarization axis R of the color polarizer 15 is allowed to pass through the color polarizer 15.

The polarization direction is changed by 90° by the next stage of the liquid crystal cell 24b in the OFF state and therefore, R is rotated by 90° by the liquid crystal cell 24b and is allowed to transmit therethrough. The horizontal polarization axis YL (R, G) of the color polarizer 16 allows R and G to pass therethrough and therefore, the color beam becomes R since G has been cut.

The polarization direction is changed by 90° by the liquid crystal cell 25b in the OFF state and therefore, R is rotated by 90° by the liquid crystal cell 25b and is allowed to pass therethrough. Further, the vertical polarization

axis W (R, G, B) of the neutral polarizer 17 allows R, G and B to pass therethrough and therefore, the color beam finally becomes R since G and B have been cut.

When the monochromatic CRT is driven by the B signal, the liquid crystal cell 23b is brought into the OFF state, the liquid crystal cell 24a is brought into the ON state and the liquid crystal cell 25b is brought into the OFF state. The respective axes of the neutral polarizer 14 are the horizontal polarization axis O (BLACK) and the vertical polarization axis W (R, G, B) and accordingly, the incident beam W is allowed to transmit therethrough in the vertical direction. The polarization direction is changed by 90° by the liquid crystal cell 23b in the OFF state and accordingly, the color beams which have passed through the neutral polarizer 14 are rotated by the liquid crystal cell 23b and allowed to pass therethrough. Further, only G and B which are common to the horizontal polarization axis Cy (G, B) of the color polarizer 15, are allowed to pass through the color polarizer 15.

The polarization direction is not changed by the next stage of the liquid crystal cell 24a in the ON state and accordingly, G and B are allowed to transmit through the liquid crystal cell 24a as they are. Further, the horizontal polarization axis YL (R, G) of the color polarizer 16 allows R and G to pass therethrough and therefore, B is cut and the color beam becomes G.

The polarization direction is changed by 90° by the liquid crystal cell 25b in the OFF state and accordingly, G is rotated by 90° by the liquid crystal cell 25b and is allowed to pass therethrough. Further, the vertical polarization axis W (R, G, B) of the neutral polarizer 17 allows R, G and B to pass therethrough and therefore, the color beam finally becomes G since R and B have been cut.

When the monochromatic CRT is driven by the G signal, the liquid crystal cell 23b is brought into the OFF state, the liquid crystal cell 24b is brought into the OFF state and the liquid crystal cell 25a is brought into the ON state. The respective axes of the neutral polarizer 14 are the horizontal polarization axis O (BLACK) and the vertical polarization axis W (R, G, B) and accordingly, the incident beam W is allowed to pass therethrough in the vertical direction. The polarization direction is changed by 90° by the liquid crystal cell 23b in the OFF state and therefore, the color beams which have passed through the neutral polarizer 14 are rotated by 90° by the liquid crystal cell 23b and are allowed to pass therethrough. Further, only G and B which are common to the horizontal polarization axis Cy (G, B) are allowed to pass through the color polarizer 15.

The polarization direction is changed by 90° by the next stage of the liquid crystal cell 24b in the OFF state and therefore, the color beams which have passed through the

color polarizer 15, are rotated by 90° by the liquid crystal cell 24b and are allowed to pass therethrough. Further, the color beam becomes B since the vertical polarization axis B of the color polarizer 16 allows B to pass therethrough.

The polarization direction is not changed by the liquid crystal cell 25a in the ON state and accordingly, B is allowed to pass through the liquid crystal cell 25a as it is. The vertical polarization axis W (R, G, B) of the neutral polarizer 17 allows R, G and B to transmit therethrough and therefore, the color beam finally becomes B since R and G have been cut.

As has been explained, in respect of the field sections causing color shading, the polarization directions of the liquid crystal cells are controlled such that BLACK minimizing the light transmittance is selectively outputted. Thereby, color shading among the image fields caused by the delays in the response speeds of the liquid crystal cells can be prevented.

Furthermore, it is not necessary to divide the electrode of the liquid crystal cell and therefore, the structure of the liquid crystal shutter can be fabricated simply and inexpensively.

Incidentally, the monochromatic CRT is not limited to a normal type one but a flattened type CRT may be used therefor. Further, a flat display such as liquid crystals, a plasma display or the like may be adopted.

Although ON/OFF of the liquid crystal cell is carried out in accordance with a level of a voltage of the drive signal, the ON/OFF of the liquid crystal cell may be carried out by changing the frequency of the drive signal.

As has been explained, according to the present invention, the polarization direction of the liquid crystal cell is controlled such that BLACK minimizing the light transmittance is selectively outputted in the field sections causing color shading. Thereby, color shading among the image fields caused by the delay in the response speed of the liquid crystal shutter can be prevented and full color images having a high degree of color purity can be realized.



WHAT IS CLAIMED IS

1. A field sequential color display device conducting a color display by switching three primary color signals, said device comprising:

a monochromatic Cathode Ray Tube for displaying images where luminances thereof are varied;

sequential color signal forming means for forming sequential color signals for driving the monochromatic CRT from the three primary color signals;

a liquid crystal shutter comprising a plurality of color polarizers arranged in series on an optical axis in respect of the monochromatic CRT and a plurality of liquid crystal cells arranged in series on the optical axis between the plurality of color polarizers; and

polarization direction controlling means for controlling polarization directions of color beams such that a light transmittance of the liquid crystal shutter is minimized when two sheets or more of the liquid crystal cells are simultaneously turned on by driving polarization axes of the liquid crystal cells.

2. The field sequential color display device according to Claim 1, wherein said polarization direction controlling means drive simultaneously a plurality of said liquid crystal cells such that the polarization directions of said color beams are controlled in respect of a total of a face corresponding to image regions.

3. The field sequential color display device according to Claim 1, wherein said polarization direction controlling means forms drive signals for driving the polarization axes of said liquid crystal cells by which the polarization directions of said color beams are controlled in accordance with voltage levels of said drive signals.



THIS SHEET HAS BEEN
REPLACED

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FIELD SEQUENTIAL COLOR DISPLAY DEVICE

ABSTRACT

A sequential color signal forming means forms sequential color signals for driving a monochromatic CRT from the three primary color signals, a liquid crystal shutter is constituted by a plurality of color polarizers and a neutral polarizer arranged in series on an optical axis in respect of the monochromatic CRT and a plurality of liquid crystal cells arranged in series on the optical axis therebetween, a polarization direction controlling means controls polarization directions of color beams such that color shading is not caused by driving polarization axes of the liquid crystal cells by which full color images having a high degree of color purity without causing color shading is realized thereby providing a field sequential color display device preventing color shading among image fields.

FIGURE 1

This Sheet Has Been Replaced



FIG. 1

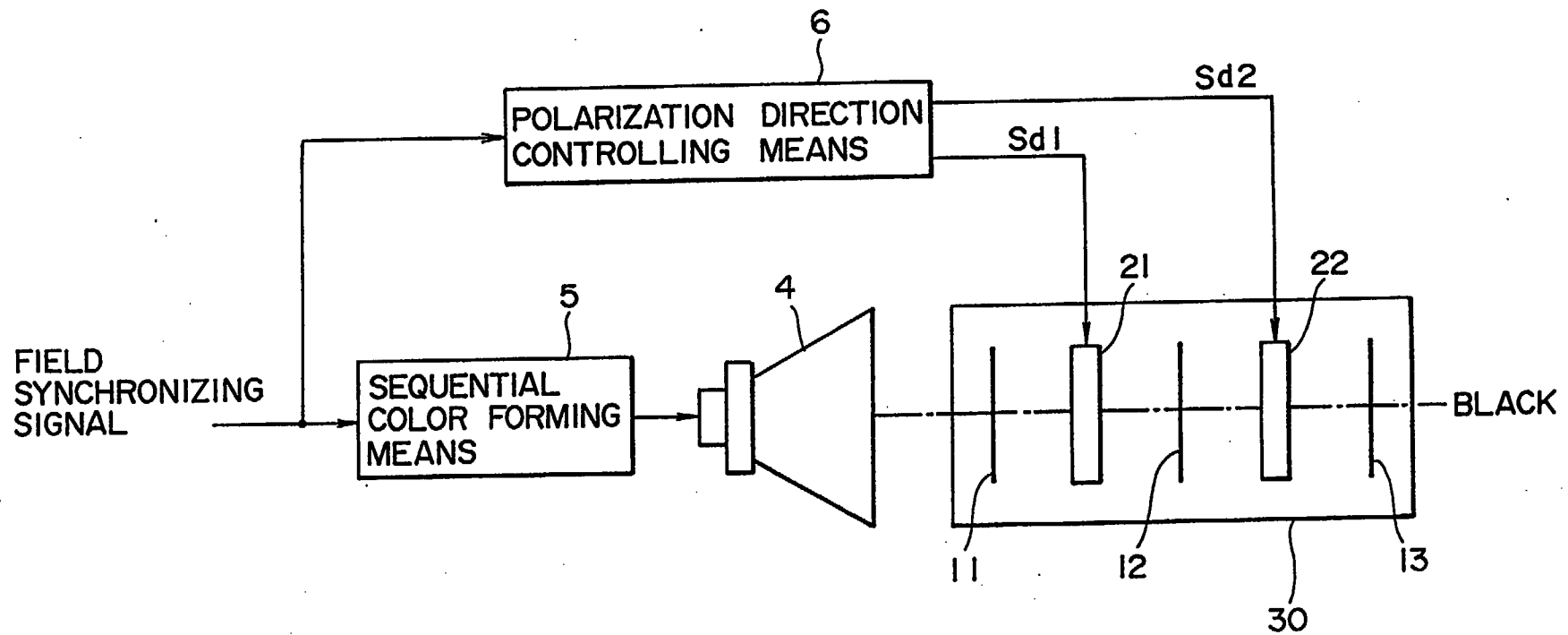


FIG. 2

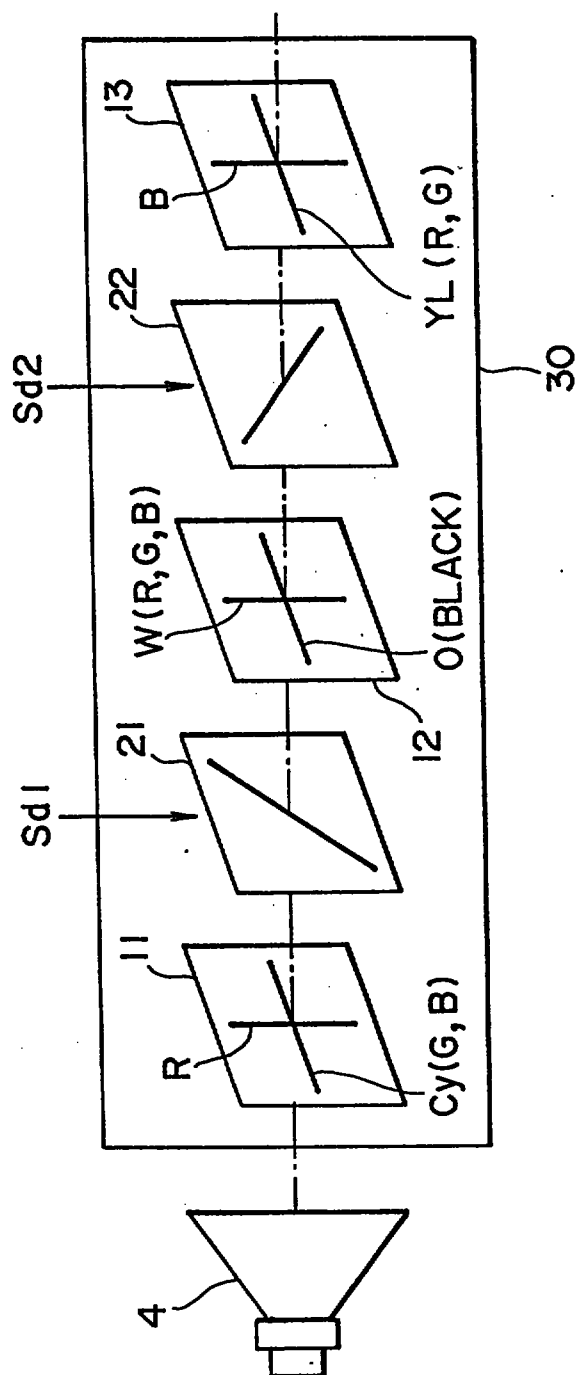


FIG. 3

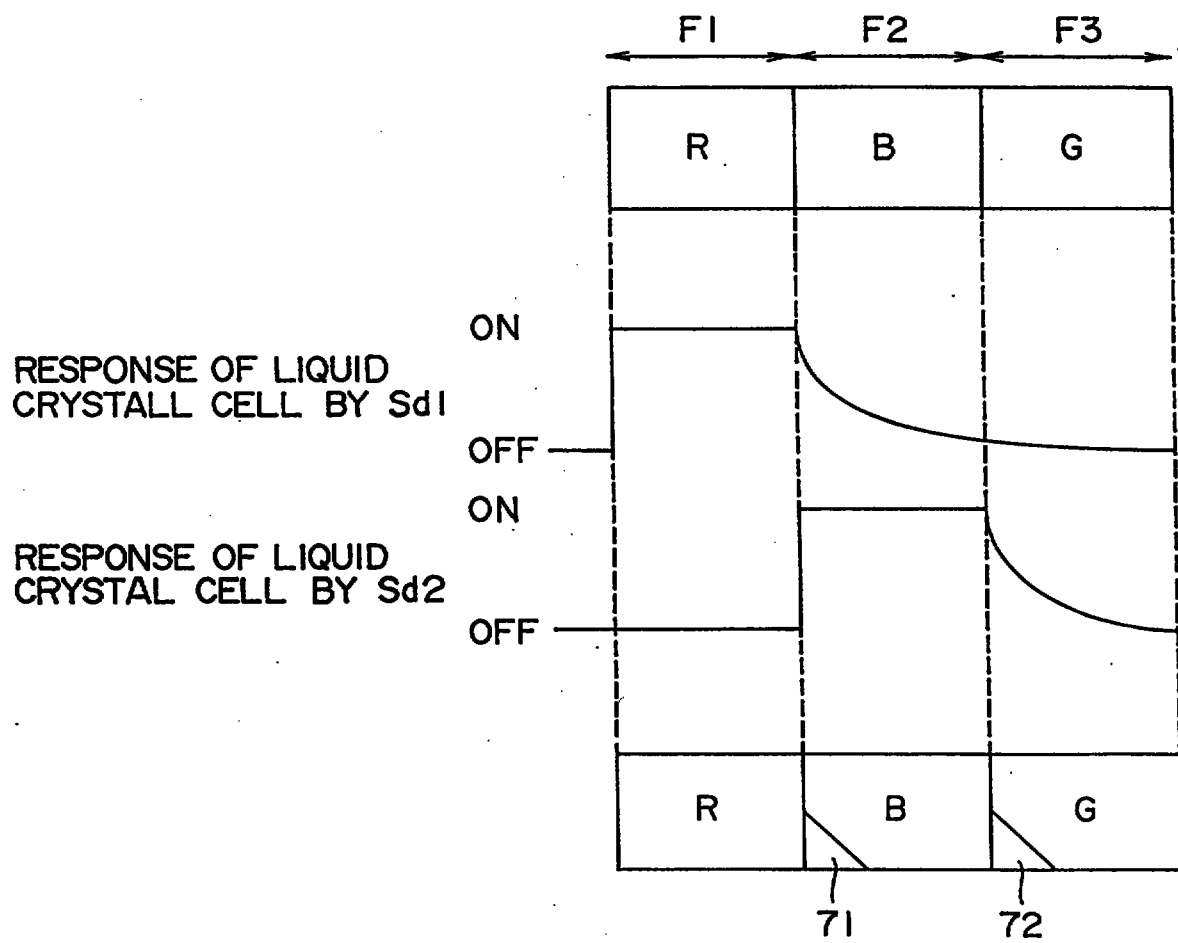


FIG. 4

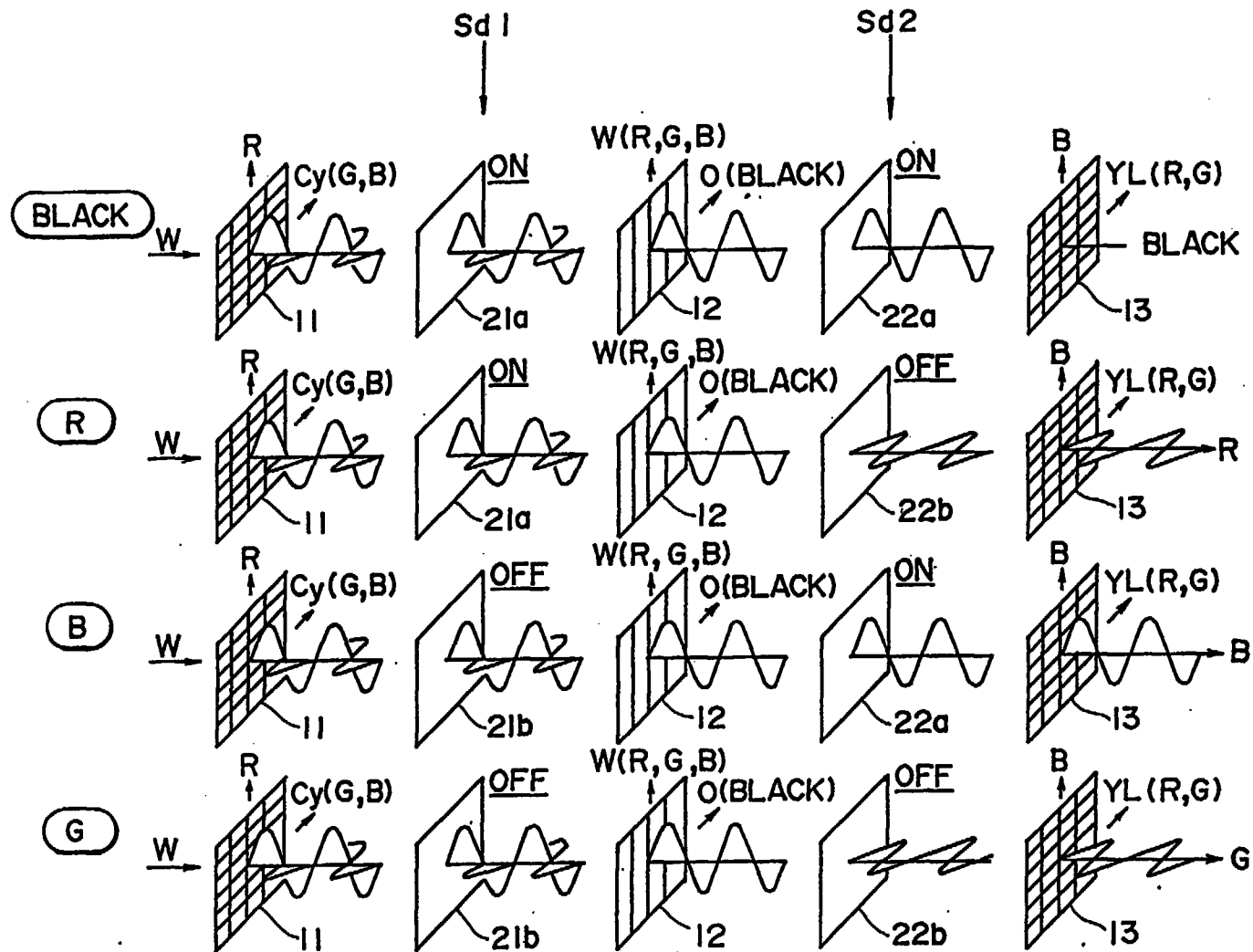


FIG. 5

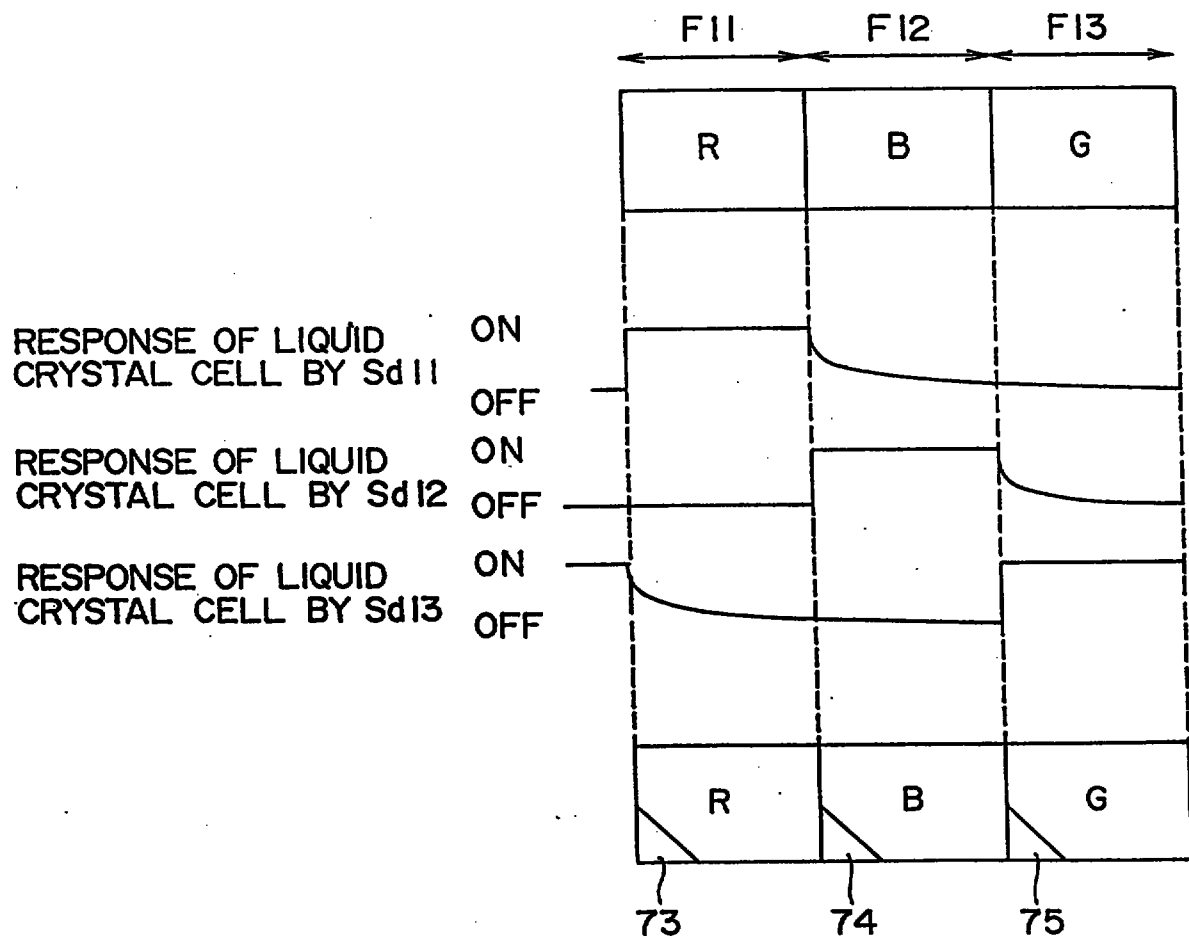


FIG. 6

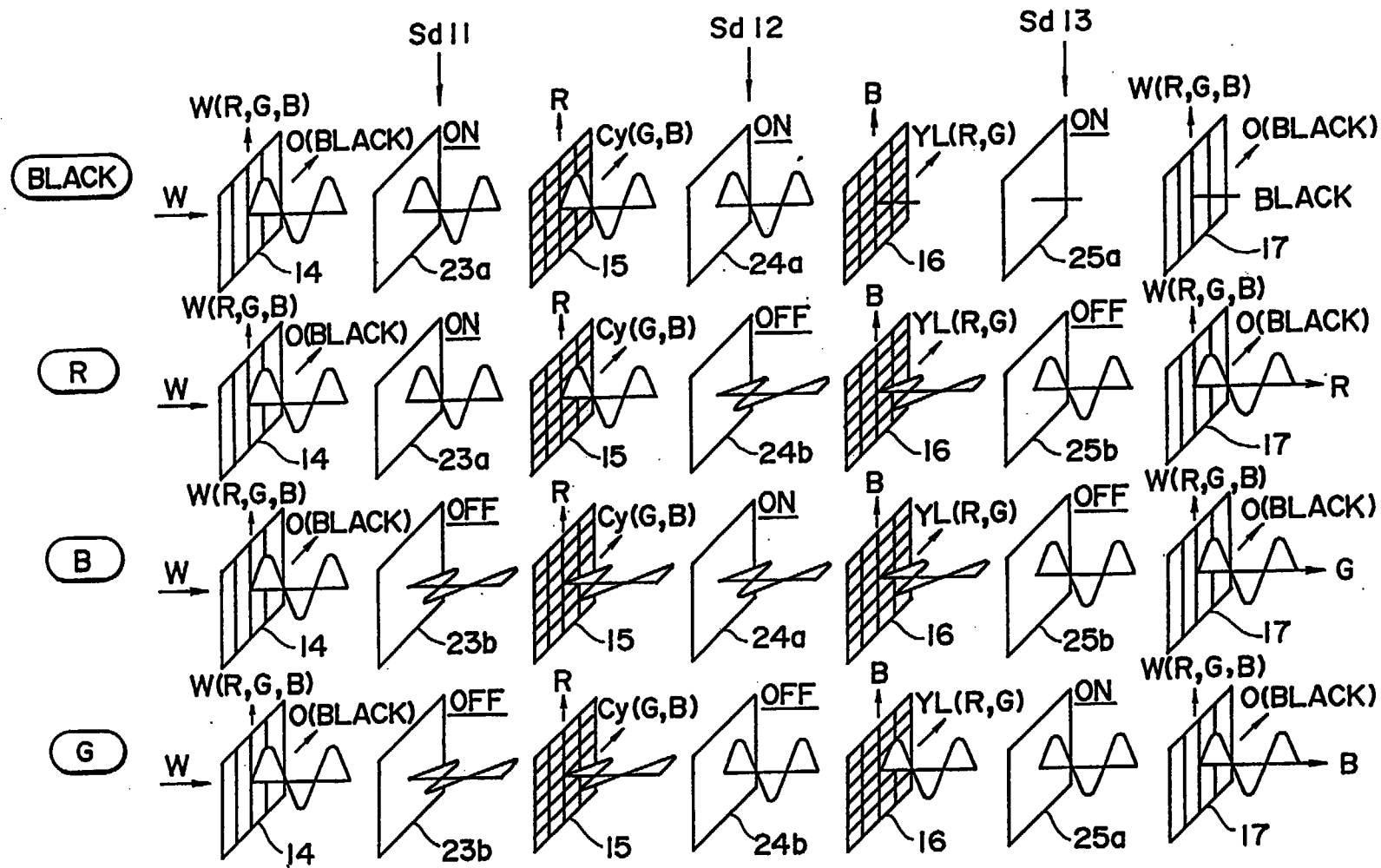


FIG. 7

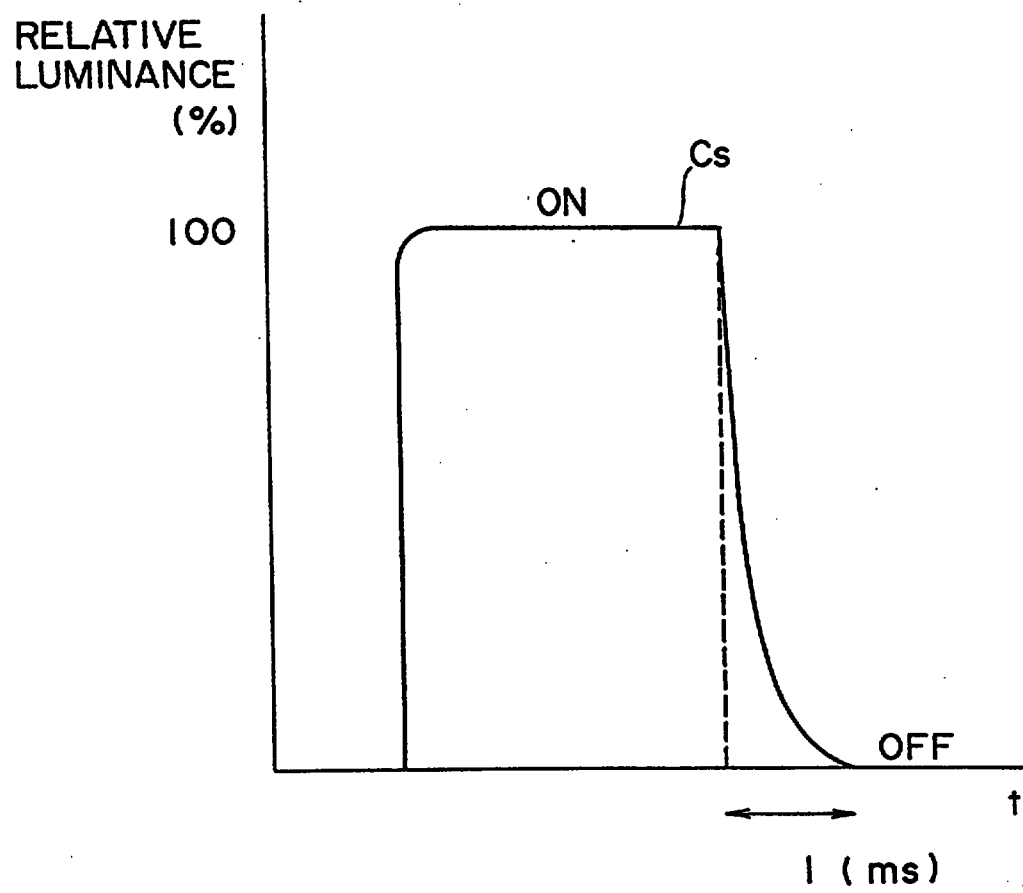
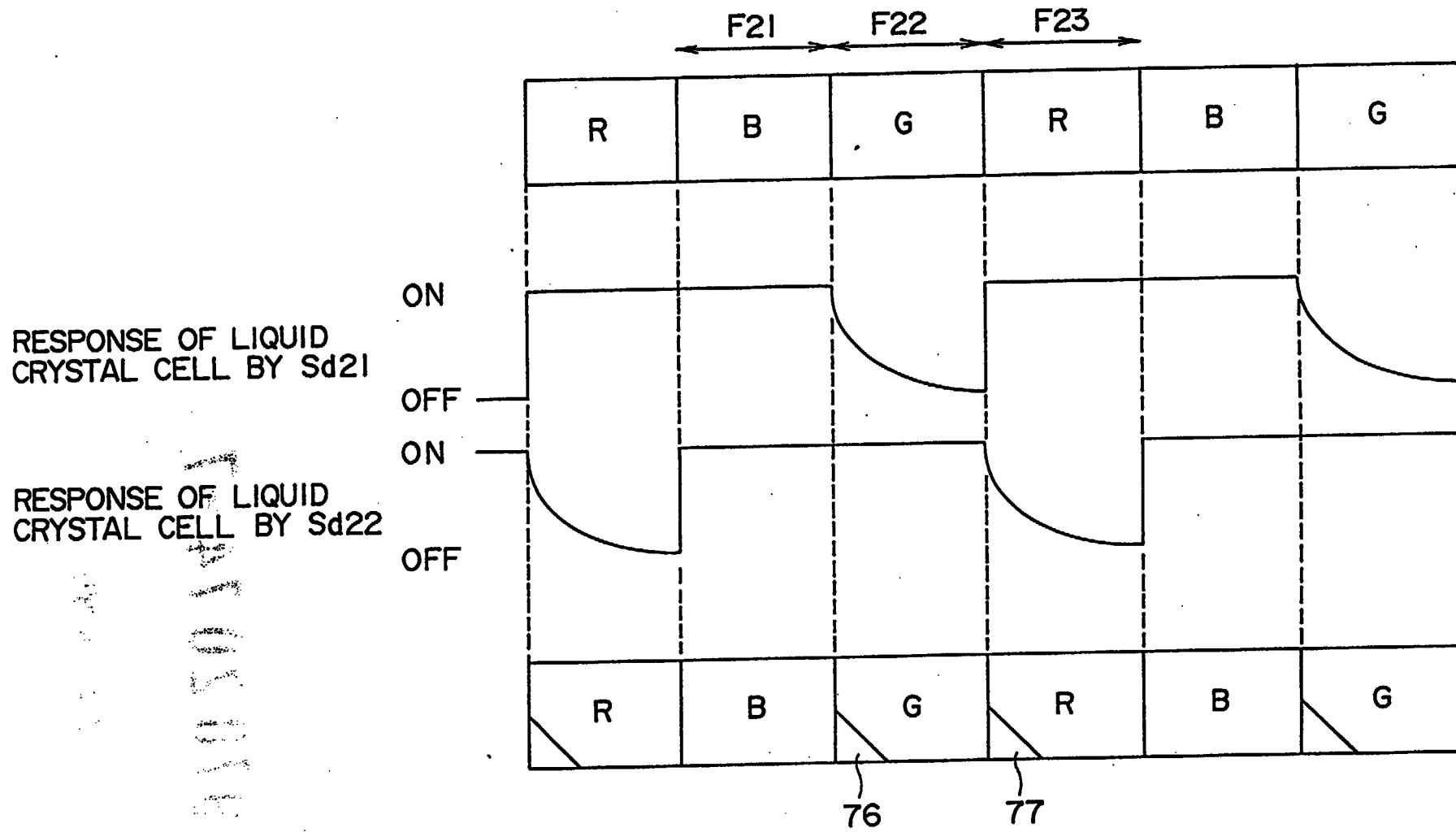


FIG. 8





TEXT OF THE ABSTRACT

FIELD SEQUENTIAL COLOR DISPLAY DEVICE

A sequential color signal forming means (5) forms sequential color signals for driving a monochromatic CRT (4) from the three primary color signals. A liquid crystal shutter (30) is constituted by a plurality of color polarizers (11,13) and a neutral polarizer (12) arranged in series on an optical axis in respect of the monochromatic CRT (4) and a plurality of liquid crystal cells (21,22) arranged in series on the optical axis therebetween. A polarization direction controlling means (6) controls polarization directions of color beams such that color shading is not caused by driving polarization axes of the liquid crystal cells (21,22) by which fullcolor images having a high degree of color purity without causing color shading is realized thereby providing a field sequential color display device preventing color shading among image fields.

Fig. 1

