

DESCRIPTION

DISPLAY DEVICE, DISPLAY METHOD, LIQUID CRYSTAL DRIVING
CIRCUIT, AND LIQUID CRYSTAL DRIVING METHOD

5 Technical Field

The present invention relates to display devices,
display methods, liquid crystal driving circuits, and liquid
crystal driving methods, and in particular to a display
device, display method, liquid crystal driving circuit, and
10 liquid crystal driving method suitable for use in displaying
information by using cholesteric liquid crystal, and to a
program and a recording medium.

Background Art

15 In liquid crystal display devices, for example, simple
matrix TN (Twisted Nematic) liquid crystal and STN (Super
Twisted Nematic) liquid crystal, active matrix TFT (Thin
Film Transistor) liquid crystal and MIM (Metal In Metal)
liquid crystal, etc., are used.

20 In the simple matrix system, X-electrodes and Y-
electrodes are arranged in grid form, and liquid crystal at
the intersections is driven by switching on and off these
electrodes with appropriate timing. Liquid crystal display
devices using the simple matrix system have a small number
25 of electrodes and can be easily produced. Accordingly, they

are less expensive than products using the active matrix system. In the simple matrix system, since electrodes of liquid crystal cells forming pixels are not independent, a voltage interferes with surrounding cells, so that it is
5 difficult to clearly display the pixels point by point. In addition, in the active matrix system, unlike the simple matrix system, each pixel is switched on and off (by respectively adding active elements to pixels for driving liquid crystal) for display. The active matrix system is
10 superior in performance to the simple matrix system in terms of a greater response speed, less residual image, broader angle of view, etc. However, its production cost is higher.

In these display devices using liquid crystal, in order to maintain display of information, it is necessary to apply
15 a voltage to the liquid crystal. When a voltage is applied to the liquid crystal for a predetermined period, a residual image phenomenon called "sticking" occurs. To prevent sticking, for example, a frame inversion technology in which voltages applied to pixel electrodes are inverted at
20 predetermined intervals, or the like, is used. When a polarity inversion technology, such as frame inversion, is employed, the amplitude of a voltage applied to signal lines needs to be double that in the case of polar driving. Accordingly, to reduce the amplitude of the voltage applied
25 to the signal lines by half, a common inversion technology,

etc., is used.

Unlike the above-described liquid crystal display devices, in liquid crystal display devices using cholesteric liquid crystal, an applied voltage causes a change of state
5 (planar and focal conic states), and this is used to display information. Furthermore, previously displayed information can be held without supplying power (e.g., "*Ekisho Debaisu Handobukku* (Liquid Crystal Device Handbook)" issued on September 29, 1989, by Nikkan Kogyo Shimbun, Ltd., pp. 352-
10 355).

Cholesteric liquid crystal selectively reflects light having a wavelength corresponding to the thickness of a liquid crystal helical layer when in its planar state, and is almost transparent when in its focal conic state.

15 By using Figs. 1 and 2, the configuration of a cholesteric liquid crystal panel 1 is described. Fig. 1 is a sectional view of the cholesteric liquid crystal panel 1, and Fig. 2 is a view illustrating the configuration of two groups of electrodes in the cholesteric liquid crystal panel
20 1.

On a glass substrate 11-1, transparent column electrodes (ITO: Indium Tin Oxide) 12 are deposited (or sputtered) in the form of stripes, and, on a glass substrate 11-2, transparent row electrodes (ITO: Indium Tin Oxide) 15
25 are deposited (or sputtered) in the form of stripes. On

surfaces of the glass substrates 11-1 and 11-2 on which the transparent column electrodes 12 and the transparent row electrodes 15 are deposited, polyimide layers 13-1 and 13-2 each having a thickness of approximately several micrometers are formed, respectively.

The glass substrates 11-1 and 11-2, which are provided with the electrodes, as described above, are bonded to each other, having a gap thickness of several micrometers (e.g., approximately 5 μm), with a gap material or the like so that the stripes of the transparent column electrodes 12 and the stripes of the transparent row electrodes 15 cross and that both oppose each other. The gap between the glass substrates 11-1 and 11-2 is filled with cholesteric liquid crystal by using, for example, vacuum filing, whereby a cholesteric liquid crystal film 14 is formed.

For the cholesteric liquid crystal panel 1, polyimide layer alignment, provision of polarizers on the glass substrates, etc., as in the case of commonly used TN liquid crystal or the like, are not required.

Cholesteric liquid crystal has special helical structure as a molecular structure. The state of the cholesteric liquid crystal is changed since the helical structure is changed by the value of a bipolar pulse voltage applied to the cholesteric liquid crystal. As shown in Fig. 3, cholesteric liquid crystal has two stable states, a focal

conic state and a planar state, based on the value of an applied bipolar pulse voltage. The planar state is a state in which a specified wavelength band of light is coherently scattered, and the focal conic state is a state in which
5 light is transmitted in a wide band.

Accordingly, the cholesteric liquid crystal panel 1 can display information by using a first color determined based on a wavelength band reflected in the planar state and a second color in which, when the cholesteric liquid crystal
10 panel 1 is transparent in the focal conic state, the second color is transmitted by the liquid crystal to be visible. In other words, in the cholesteric liquid crystal panel 1, for example, by setting the cholesteric liquid crystal to diffusely reflect light of a specified wavelength band in
15 the planar state, and blackening a portion under the cholesteric liquid crystal layer 14 so that the black color is transmitted to be visible in the focal conic state, whereby monotone display of the specified wavelength color and black color can be performed.

20 As shown in Fig. 3, the voltage value V_{ps} of the bipolar pulse voltage required for changing the state of the cholesteric liquid crystal to the planar state is approximately double the voltage value V_{fs} of the bipolar pulse voltage required for changing to the focal conic state.

25 After the cholesteric liquid crystal is set to the

focal conic state or the planar state by applying a bipolar pulse voltage to predetermined pixel electrodes, the set state can be held if no voltage is applied. When the bipolar pulse voltage is applied again, its voltage value
5 can change the state of the cholesteric liquid crystal, if necessary. In other words, the cholesteric liquid crystal panel 1 using cholesteric liquid crystal can maintain information displayed by applying the bipolar pulse voltage without being subsequently supplied with power.

10 Fig. 4 shows an example of a driving voltage waveform applied to the pixel electrodes when display of predetermined pixels in the cholesteric liquid crystal panel 1 is changed. When, in the focal conic state, the bipolar pulses of voltage V_{ps} are applied to the predetermined pixel
15 electrodes, the planar state is activated to change the displayed color to the first color. When, in the planar state, the bipolar pulses of voltage V_{fs} are applied to the predetermined pixel electrodes, the focal conic state is activated to change the displayed color from the first color
20 to the second color.

In the cholesteric liquid crystal panel 1, after the displayed information is temporarily reset, for example, such that the entire display surface is set to the planar state by applying the bipolar pulses of voltage value V_{sp} to
25 the entire panel, predetermined information is displayed

such that the state is changed to the focal conic state by applying the bipolar pulses of voltage value V_{fs} to the pixel electrodes at necessary positions, and no voltage is applied after that, whereby the displayed information can be
5 held.

Fig. 5 is a block diagram showing an example of the configuration of a liquid crystal driving circuit 21 of the related art for driving the cholesteric liquid crystal panel 1. Here, the cholesteric liquid crystal panel 1 is
10 described assuming that it displays information of $n \times m$ pixels.

A column driver 31 is supplied with a clock (CLK) signal and a data (DATA) signal representing information to be displayed on the cholesteric liquid crystal panel 1 and
15 is connected to driving voltage $\pm V_2$ and GND (0 V). It applies a predetermined voltage to column (signal) electrodes Y_1 to Y_n of the transparent column electrodes 12 in the cholesteric liquid crystal panel 1 with predetermined timing, which is described later by using Fig. 7.

20 A row driver 32 is supplied the clock (CLK) signal and is connected to driving voltage $\pm V_1$ and GND which is common to GND supplied to the column driver 31. It applies a predetermined voltage to row (scanning) electrodes X_1 to X_m of the transparent row electrodes 15 in the cholesteric
25 liquid crystal panel 1 with predetermined timing, which is

described later by using Fig. 7.

Here, driving voltage V_1 and driving voltage V_2 are voltage values satisfying $V_1 + V_2 > V_{ps}$.

Next, a specific example of the case of using two
5 colors (two colors, that is, a specified wavelength color and black, and, when the specified wavelength color is, for example, white, the pixels are displayed in two colors, black and white) to display nine pixels composed of 3×3 pixels is described.

10 For example, a case in which, as shown in Fig. 6, among nine pixels composed of 3×3 pixels, six pixels, (X_1, Y_1) , (X_1, Y_2) , (X_2, Y_2) , (X_2, Y_3) , (X_3, Y_2) , and (X_3, Y_3) , are displayed in black and the other three pixels are displayed in the specified wavelength color is described. Display of
15 the specified wavelength color is a state in which light having the specified wavelength color is coherently scattered by the cholesteric liquid crystal, which is in the planar state, and display of black is a state in which black is displayed after being transmitted by the cholesteric
20 liquid crystal, which is in the focal conic state.

Figs. 7 and 8 are timing charts showing the operation of the column driver 31 and the row driver 32. Fig. 7 is a timing chart showing the voltage and timing of bipolar pulses applied to column electrodes X_1 to X_2 by the column
25 driver 31, and the voltage and timing of bipolar pulses

applied to row electrodes Y1 to Y3 by the row driver 32, for allowing the cholesteric liquid crystal panel 1 to display information of nine pixels composed of 3×3 pixels as shown in Fig. 6. Fig. 8 is a timing chart illustrating bipolar
5 pulses which are applied to inter-pixel-electrode portions (electrode portions serving as intersections of the transparent column electrodes 12 and the transparent row electrodes 15) of nine pixels, composed of 3×3 pixels, (X1, Y1) to (X3, Y3), having the applied voltage described by
10 using Fig. 7.

At first, to reset information presently held, as shown in Fig. 7, bipolar pulses having voltage V1 are applied to column electrodes Y1 to Y3, and bipolar pulses having voltage -V2 are applied to row electrodes X1 to X3.
15 Accordingly, as shown in Fig. 8, bipolar pulses having $V1+V2$ are applied to the inter-pixel-electrode portions corresponding to pixels (X1, Y1) to (X3, Y3). Here, since $V1+V2 > V_{ps}$, the cholesteric liquid crystal layer 14 between the transparent column electrodes 12 and the transparent row
20 electrodes 15 enters the planar state to coherently reflect specified wavelength light. In other words, all the pixels (X1, Y1) to (X3, Y3) display the specified wavelength color (this is referred to as entire planar resetting).

After that, as shown in Fig. 7, the row driver 32
25 selects one row electrode by applying bipolar pulses having

voltage V_3 to sequentially scan from row electrode X_1 to row electrodes X_2 and X_3 . In addition, the column driver 31 selectively applies inverse-characteristic bipolar pulses $-V_4$ to column electrodes Y_1 to Y_3 in response to the row electrode selecting timing. Here, $V_3 + V_4 > V_{fs}$, where $V_1 > V_3$ and $V_2 > V_4$.

As shown in Fig. 8, a bipolar pulse voltage of $V_3 + V_4 > V_{fs}$ is applied to the six pixels, (X_1, Y_1) , (X_1, Y_2) , (X_2, Y_2) , (X_2, Y_3) , (X_3, Y_2) , and (X_3, Y_3) , which correspond to the pixel electrodes to which the bipolar pulses are applied to the row and column electrodes with the same timing. Thus, the cholesteric liquid crystal layer 14 between two groups of electrodes, the transparent column electrodes 12 and the transparent row electrodes 15, which are at the corresponding pixel positions, enters the focal conic state to become transparent. In other words, the six pixels, (X_1, Y_1) , (X_1, Y_2) , (X_2, Y_2) , (X_2, Y_3) , (X_3, Y_2) , and (X_3, Y_3) , are displayed in black.

In addition, $V_3 + V_4 > V_{fs}$, and voltage value V_{ps} is approximately double the voltage value V_{fs} . Thus, $V_1 + V_2 > V_3 + V_4$ holds.

As described above, after temporarily performing entire planar resetting on the display on the cholesteric liquid crystal panel 1, by inverting the color of arbitrary pixels from the specified wavelength color to black, information

can be displayed.

The driving voltage required for the column driver 31 and row driver 32 in the liquid crystal driving circuit 21 described by using Fig. 5 to drive the cholesteric liquid crystal panel 1 is the lowest value of $(V1+V2)/2$ when $V1 = V2$. Thus, the breakdown voltage of the column driver 31 and the row driver 32 must be equal to or greater than $(V1+V2)/2$.

Although bipolar pulse voltage Vps for changing the state to the planar state and bipolar pulse voltage Vfs for changing the state to the focal conic state differ depending on inter-electrode gap thickness, for example, when the gap thickness is 5 μm , it is required that $Vps =$ approximately 40 V, and $Vfs =$ approximately 20 V. Accordingly, to satisfy $V1+V2 > Vps$, the column driver 31 and the row driver 32 each require a breakdown voltage of approximately 20 V.

It is very difficult to reduce the size and cost of driving circuits for driving the cholesteric liquid crystal.

Disclosure of Invention

Embodiments of the present invention reduce a voltage value supplied as a driving voltage to each driver for driving cholesteric liquid crystal.

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According to a first aspect of the present invention, there is provided a display device comprising: a display means in which, by applying voltages to row

electrodes and column electrodes, the state of cholesteric liquid crystal is changed to display information; a row driver for applying a voltage to the row electrodes; a column driver for applying a voltage to the column electrodes; a row-driver-reference-voltage switching means for selectively switching a first reference voltage (e.g., GND_r) supplied to the row driver between a first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar voltage required for setting the state of the cholesteric liquid crystal to a planar state, and a zero volts; a column-driver-reference-voltage selectively switching means for switching a second reference voltage (e.g., GND_c) supplied to the column driver between a second voltage ($-V_1-V_2$) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage, and zero volts; and a control means for controlling the operation of the row driver and the column driver, the row-driver-reference-voltage switching means, and the column-driver-reference-voltage switching means. A driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage (e.g., V_3). A driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage (e.g., V_4). The sum of the third voltage and the fourth voltage is a voltage value greater than the

voltage value required for setting the state of the cholesteric liquid crystal to a focal conic state. When the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the row electrodes and the second reference voltage is applied to the column electrodes, and, in order to set a desired portion of the cholesteric liquid crystal to the focal conic state, the control means controls the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means to switch each of the first reference voltage and the second reference voltage to zero volts, and controls the row driver and the column driver to control supply of the first bipolar driving voltage and the second bipolar driving voltage to the cholesteric liquid crystal.

The row driver may be supplied with the first bipolar driving voltage, the column driver may be supplied with the second bipolar driving voltage, the first bipolar driving voltage and the second bipolar driving voltage each may be a voltage value in which the sum (e.g., V_3+V_4) of the absolute

values of the third voltage and the fourth voltage is approximately a half of the first voltage, and, when the control means sets the desired portion of the cholesteric liquid crystal to the focal conic state, the control means may control the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and may control the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

According to a second aspect of the present invention, there is provided a display method for a display device comprising a display unit which displays information with cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the display method including: a first reference-voltage applying step of supplying zero volts as a first reference voltage (e.g., GND_r) to a row driver which applies a voltage to row electrodes and supplying the first reference voltage to the row electrodes; a second reference-voltage applying step of supplying zero volts as a second reference voltage (e.g., GND_c) to a column driver which applies a voltage to column electrodes and applying the first reference voltage to the row electrodes; a first reference-voltage control step of, in order to set the cholesteric liquid

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crystal to a planar state, controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar driving voltage required

for setting the state of the cholesteric liquid crystal to the planar state; a second reference-voltage control step of, in order to set the cholesteric liquid crystal to the planar state, controlling the second reference voltage applied to the column driver to perform switching from zero volts to a second voltage (e.g., $-V_1-V_2$) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage; a third switching step (e.g., S7 in Fig. 12) of, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, controlling the first reference voltage applied to the row driver to perform switching from the first voltage to zero volts, and controlling a second driving voltage applied to the column driver to perform switching from the second voltage to zero volts; and a display control step of controlling display of information on the display unit by, in order to set the desired portion of the cholesteric liquid crystal to the focal conic state, applying a first bipolar driving voltage so as to scan the row electrodes, and selectively applying a second bipolar driving voltage to the column electrodes, the second bipolar driving voltage having an absolute value equal to the first voltage and being reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes. A driving voltage supplied the row driver is the first bipolar driving voltage, whose absolute value

is a third voltage (e.g., V_3), a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a fourth voltage (e.g., V_4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to a focal conic state.

The first bipolar driving voltage and the second bipolar driving voltage each may have a voltage value in which the sum (e.g., V_3+V_4) of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage.

In the first and second aspects of the present invention, after the reference voltage applied to the row electrodes is controlled to perform switching from zero volts to the first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar voltage required for setting the state of cholesteric liquid crystal to the planar state, the reference voltage applied to the column electrodes is controlled to perform switching from zero volts to the second voltage (e.g., $-V_1-V_2$) whose absolute value is the first voltage and which is reverse in polarity to the first voltage, whereby the cholesteric liquid crystal is changed to be in the planar state.

According to a third aspect of the present invention, there is provided a liquid crystal driving circuit

for driving liquid crystal display elements including cholesteric liquid crystal, the liquid crystal driving circuit comprising: a row driver for applying a voltage to row electrodes of a liquid crystal display element; a column driver for applying a voltage to column electrodes of the liquid crystal display element; a row-driver-reference-voltage switching means for selectively switching a first reference voltage (e.g., GND_r) supplied to the row driver between a first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar driving voltage required to setting the state of the cholesteric liquid crystal to a planar state, and zero volts; a column-driver-reference-voltage switching means for selectively switching a second reference voltage (e.g., GND_c) supplied to the column driver between a second voltage (e.g., $-V_1-V_2$) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage, and zero volts; and a control means for controlling operation of the row driver and the column driver, and the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means. A driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage (e.g., V_3), a driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage (e.g., V_4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for

setting the state of the cholesteric liquid crystal to a focal conic state. When the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means
5 to set the first reference voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the
10 row electrodes and the second reference voltage is applied to the column electrodes, and, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, the control means controls the row-driver-reference-voltage switching means and the column-driver-reference-
15 voltage switching means to switch each of the first reference voltage and the second reference voltage to zero volts, and controls the row driver and the column driver to control supply to the cholesteric liquid crystal of the first bipolar driving voltage and the second bipolar driving
20 voltage.

The row driver may be supplied with the first bipolar driving voltage, the column driver may be supplied with the second bipolar driving voltage, the first bipolar driving voltage and the second bipolar driving voltage each may be a
25 voltage value in which the sum of the absolute values of the

third voltage and the fourth voltage is approximately a half of the first voltage, and, when the control means sets the desired portion of the cholesteric liquid crystal to the focal conic state, the control means may control the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and may control the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

According to a fourth aspect of the present invention, there is provided a liquid crystal driving method for a liquid crystal driving circuit which drives liquid crystal display elements including cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the liquid crystal driving method including: a first reference-voltage applying step of supplying zero volts as a first reference voltage (e.g., GND_r) to a row driver which applies a voltage to the row electrodes and supplying the first reference voltage to the row electrodes; a second reference-voltage applying step of supplying zero volts as a second reference voltage (e.g., GND_c) to a column driver which applies a voltage to the column electrodes and applying the first reference voltage to the row electrodes; a first reference-voltage control step of, in order to set the cholesteric liquid crystal to a planar state,

driving voltage required for setting the state of the
cholesteric liquid crystal to the planar state; a second
reference-voltage control step of, in order to set the
cholesteric liquid crystal to the planar state, controlling
5 the second reference voltage applied to the column driver to
perform switching from zero volts to a second voltage (e.g.,
-V1-V2) whose absolute value is equal to the first voltage
and which is reverse in polarity to the first voltage; a
third switching step (e.g., S7 in Fig. 12) of, in order to
10 set a desired portion of the cholesteric liquid crystal to a
focal conic state, controlling the first reference voltage
applied to the row driver to perform switching from the
first voltage to zero volts, and controlling a second
driving voltage applied to the column driver to perform
15 switching from the second voltage to zero volts; and a
driving-voltage-application control step of, in order to set
the desired portion of the cholesteric liquid crystal to the
focal conic state, controlling sequential application of a
first bipolar driving voltage to the row electrodes, and
20 controlling selective application, to the column electrodes,
of a second bipolar driving voltage having a voltage value
which is reverse in polarity to the first bipolar driving
voltage applied so as to scan the row electrodes, and whose
absolute value is equal to the first voltage. A driving
25 voltage supplied the row driver is the first bipolar

controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar driving voltage, whose absolute value is a third voltage (e.g., V_3), a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a fourth voltage (e.g., V_4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to the focal conic state.

The first bipolar driving voltage and the second bipolar driving voltage each may be a voltage value in which the sum (e.g., V_3+V_4) of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage.

In the third and fourth aspects of the present invention, after the reference voltage applied to the row electrodes is controlled to perform switching from zero volts to the first voltage having a voltage value (e.g., V_1+V_2) greater than the absolute value of the bipolar voltage required for setting the state of cholesteric liquid crystal to the planar state, the reference voltage applied to the column electrodes is controlled to perform switching from zero volts to the second voltage (e.g., $-V_1-V_2$) whose absolute value is the first voltage and which is reverse in polarity to the first voltage, whereby the cholesteric liquid crystal is changed to be in the planar state.

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20 Brief Description of the Drawings

Fig. 1 is an illustration of a cholesteric liquid crystal panel.

Fig. 2 is an illustration of the cholesteric liquid crystal panel.

25 Fig. 3 is a graph illustrating states of cholesteric

liquid crystal and a bipolar pulse voltage applied.

Fig. 4 is a chart of a waveform for cholesteric liquid crystal.

Fig. 5 is a block diagram showing a liquid crystal
5 driving circuit of the related art.

Fig. 6 is an illustration of an example of data displayed.

Fig. 7 is a timing chart showing, in the liquid crystal driving circuit in Fig. 5, voltages applied to row
10 electrodes and column electrodes.

Fig. 8 is a timing chart showing, in the liquid crystal driving circuit in Fig. 5, bipolar pulse voltages each applied across the electrodes of each pixel in the cholesteric liquid crystal panel.

Fig. 9 is a block diagram showing a liquid crystal
15 driving circuit to which the present invention is applied.

Fig. 10 is a timing chart showing, in the liquid crystal driving circuit in Fig. 9, voltages applied to row electrodes and column electrodes, and GND levels.

Fig. 11 is a timing chart showing, in the liquid
20 crystal driving circuit in Fig. 9, bipolar pulse voltages each applied across the electrodes of each pixel in the cholesteric liquid crystal panel.

Fig. 12 is a flowchart illustrating processing of the
25 liquid crystal driving circuit in Fig. 9.

Best Mode for Carrying Out the Invention

An embodiment of the present invention is described below with reference to the drawings.

5 Fig. 9 is a block diagram showing the configuration of a liquid crystal driving circuit 41, for driving a cholesteric liquid crystal panel 1, to which the present invention is applied. The cholesteric liquid crystal panel 1, the liquid crystal driving circuit 41, and a power supply
10 unit (e.g., a battery or the like), which is not shown, constitute a liquid crystal display device.

The cholesteric liquid crystal panel 1 is similar to the cholesteric liquid crystal panel of the related art, which is described by using Figs. 1 to 4.

15 In other words, in the cholesteric liquid crystal panel 1, when bipolar pulses by which the potential difference between pixel electrodes reaches V_{ps} or greater is applied, cholesteric liquid crystal in a portion corresponding to the pixel position enters a planar state, whereby a
20 corresponding pixel is displayed in first color determined based on a wavelength band reflected in the planar state. In addition, in the cholesteric liquid crystal panel 1, when bipolar pulses by which the potential difference between pixel electrodes reaches V_{fs} or greater, cholesteric liquid
25 crystal corresponding to the pixel position enters a focal

conic state, whereby a corresponding pixel is displayed in second color that becomes visible after being transmitted by liquid crystal.

Here, the cholesteric liquid crystal panel 1 is
5 described assuming that a specific wavelength color and block are displayed in monotone such that the cholesteric liquid crystal is set to diffusely reflect light having specific wavelength color in the planar state, and that a portion under the cholesteric liquid crystal layer 14 is
10 blackened and the black color is made transparently visible. The first color determined based on the wavelength band reflected in the planar state, that is, a specific wavelength color, may be any color such as, for example, green, blue, or red, and also the second color that becomes
15 visible after being transmitted by the liquid crystal may be any color.

Furthermore, obviously, by providing a plurality of cholesteric liquid crystal layers 14 that respectively reflect different wavelength bands in the planar state,
20 multicolor display with the cholesteric liquid crystal panel 1 can be performed.

In addition, as shown in Fig. 3, the voltage value V_{ps} of the bipolar pulse voltage required for changing the cholesteric liquid crystal state to the planar state is
25 approximately the double the voltage vale V_{fs} of the bipolar

pulse voltage required for changing to the focal conic state.

In the cholesteric liquid crystal panel 1, after displayed information is reset (entire planar resetting) by, for example, applying bipolar pulses having voltage value
5 Vps to the entirety of the panel so that the entire display surface is in the planar state, predetermined information is displayed by applying bipolar pulses having voltage value Vfs to pixel electrodes at necessary positions so that the state is changed to the focal conic state, and, after that,
10 the displayed information is held by applying no voltage.

A controller 51 controls a column driver 52 and a row driver 53, supplies the column driver 52 with a clock (CLK) signal and data (DATA) representing information to be displayed on the cholesteric liquid crystal panel 1, and
15 supplies the row driver 53 with the clock (CLK) signal. In addition, by controlling switching of switches 54 and 55, the voltage values of GNDc, which is a reference voltage supplied to the column driver 52, and GNDr, which is a reference voltage connected to the row driver 53, are
20 switched with predetermined timing.

The column driver 52 is supplied with the clock (CLK) signal and data (DATA) signal for displaying information on the cholesteric liquid crystal panel 1 from the controller 51. The column driver 52 is also connected to driving
25 voltage $\pm V4$ and reference voltage GNDc, and is controlled by

the controller 51 to apply, with predetermined timing, which is described later by using Fig. 10, a predetermined voltage to column (signal) electrodes Y1 to Yn of transparent column electrodes 12 in the cholesteric liquid crystal panel 1.

- 5 The row driver 53 is supplied with the clock (CLK) signal from the controller 51. In addition, it is connected to driving voltage $+V3$ and reference voltage GND_r , and is controlled by the controller 51 to apply, with predetermined timing, which is described later by using Fig. 10, a
- 10 predetermined voltage to row (scanning) electrodes X1 to Xm of transparent row electrodes 15 in the cholesteric liquid crystal panel 1.

- Here, voltage $(-V1-V2)$ that is connected to reference voltage GND , or voltage $(V1+V2)$ that is connected to
- 15 reference voltage GND_r , by the switching of the switches 54 and 55, is a voltage value satisfying $V1+V2 > V_{ps}$. In addition, voltage $V4$ supplied to the column driver 52 and voltage $V3$ supplied to the row driver 53 are voltage values which satisfy $V3+V4 > V_{fs}$ and $V_{fs} > V3$ and $V_{fs} > V4$.

- 20 The switches 54 and 55 include switching elements such as, for example, FETs (Field Effect Transistors). Based on the control of the controller 51, the switch 54 switches the voltage value of reference voltage GND_c connected to the column driver 52 between $(-V1-V2)$ and GND (0 V). Based on
- 25 the control of the controller 51, the switch 55 switches the

voltage value of reference voltage GNDr between (V1+V2) and GND (0 V).

As the switches 54 and 55, obviously, those other than the FETs may be used if they can switch the voltage value of GNDc connected to the column driver 52 or the voltage value of GNDr supplied to the row driver 53 based on the control of the controller 51.

In addition, a drive 56 is connected to the controller 51, if necessary. In the drive 56, a magnetic disk 61, an optical disk 62, a magneto-optical disk 63, or a semiconductor memory 64 can be loaded so that information can be sent and received.

Figs. 10 and 11 are timing charts illustrating the operation of the column driver 52 and the row driver 53 in a case in which, after entire planar resetting is performed on the presently displayed information, the cholesteric liquid crystal panel 1 displays nine pixels, composed of 3×3 pixels in which six pixels, (X1, Y1), (X1, Y2), (X2, Y2), (X2, Y3), (X3, Y2), and (X3, Y3), are black and the other pixels are in specific wavelength color, as shown in Fig. 6.

Fig. 10 is a timing chart illustrating, in addition to the voltage and timing of bipolar pulses that are applied to column electrodes X1 to X3 by the column driver 52 in order to display information of nine pixels composed of 3×3 pixels as shown in Fig. 6 after entire planar resetting on

the presently displayed information is performed, and the voltage and timing of bipolar pulses that are applied to row electrodes Y1 to Y3 by the row driver 53, and voltage that is given as reference voltage GNDc and reference voltage GNDr by the switching of the switches 54 and 55 and the timing thereof. Fig. 11 is a timing chart illustrating bipolar pulses that are applied to the nine pixels (X1, Y1) to (X3, Y3), which have 3×3 pixels, with the applied voltages described by using Fig. 10.

At first, the switches 54 and 55 are controlled by the controller 51, so that GNDc supplied to the column driver 52 and GNDr supplied to the row driver 53 have GND (0 V).

In order to reset the presently displayed information, bipolar pulses having a voltage equal to or greater than V_{ps} must be applied to each of pixels (X1, Y1) to (X3, Y3).

Based on the control of the controller 51, the row driver 53 applies GNDr to row electrodes X1 to X3, and the column driver 52 applies GNDc to column electrodes Y1 to Y3. In addition, as shown in Fig. 10, for entire planar resetting, the controller 51 controls the switch 55 to supply voltage ($V1+V2$) to GNDr in a predetermined time width (time width determined by an application time of bipolar pulses), and controls the switch 54 with the next timing to supply voltage ($-V1-V2$) to GNDc.

Accordingly, as shown in Fig. 11, the voltage output to

row electrodes X1 to X3 by the row driver 53 is a pulse voltage of $(V1+V2)$. In addition, the voltage output to column electrodes Y1 to Y3 by the column driver 52 is a pulse voltage of $(-V1-V2)$, as shown in Fig. 11, and the
5 application timing is timing subsequent to the application of GNDr to row electrodes X1 to X3.

Accordingly, as shown in Fig. 11, bipolar pulses of $V1+V2$ are applied to pixel electrodes corresponding to pixels (X1, Y1) to (X3, Y3). Here, $V1+V2 > Vps$. Thus, the
10 cholesteric liquid crystal layer 14, between two electrodes, one transparent column electrode 12 and one transparent row electrode 15 at each corresponding pixel position, enters the planar state to coherently scatter specified wavelength light. Specifically, all displayed pixels (X1, Y1) to (X3,
15 Y3) come to have a specified wavelength color, so that they enter an entire planar resetting state.

After that, based on the control of the controller 51, the row driver 53 selects one row electrode by applying bipolar pulses having voltage $V3$ so as to perform sequential
20 scanning from row electrode X1 to row electrodes X2 and X3, as shown in Fig. 10. Also, based on the control of the controller 51, the column driver 52 selectively applies inverse-characteristic bipolar pulses $-V4$ to column electrodes Y1 to Y3 in response to timing of row electrode
25 selection, as shown in Fig. 10. Specifically, the column

driver 52 applies inverse-characteristic bipolar pulses $-V_4$ to column electrodes Y_1 and Y_2 when row electrode X_1 is selected, applies inverse-characteristic bipolar pulses $-V_4$ to column electrodes Y_2 and Y_3 when row electrode X_2 is selected, and applies inverse-characteristic bipolar pulses $-V_4$ to column electrodes Y_2 and Y_3 when row electrode X_3 is selected.

As shown in Fig. 11, a bipolar pulse voltage of $V_3+V_4 > V_{fs}$ is applied between pixel electrodes in which the bipolar pulses are applied to the row and column electrodes with the same timing. Thus, the cholesteric liquid crystal layer 14 between two electrodes, the transparent column electrode 12 and the transparent row electrode 15, at the corresponding pixel position, enters the focal conic state to become transparent. In other words, selected six pixels, (X_1, Y_1) , (X_1, Y_2) , (X_2, Y_2) , (X_2, Y_3) , (X_3, Y_2) , and (X_3, Y_3) , are displayed in black, and the other pixels remain displayed in specified wavelength color.

In the liquid crystal driving circuit 41 to which the present invention is applied, when, for example, $V_3 = V_4$, a driving voltage of the column driver 52 and the row driver 53 is $(V_3+V_4)/2$. Since $V_3+V_4 > V_{fs}$ and voltage value V_{ps} is approximately double voltage value V_{fs} , $(V_3+V_4) \approx 1/2(V_1+V_2)$ holds. Therefore, in the liquid crystal driving circuit 41 to which the present invention is applied, compared with the

case of the related art, each driving voltage of the column driver 52 and the row driver 53 can be reduced to approximately a half.

As described above, in the liquid crystal display device including the liquid crystal driving circuit 41 to which the present invention is applied, by resetting display while suppressing the voltages supplied as driving voltages to the drivers, the color of arbitrary pixels can be inverted from a specified wavelength color to black.

10 In addition, the driving voltages of drivers (here, the column driver 52 and the row driver 53) of the liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1 decrease, whereby elements whose package is small can be selected for the drivers. Thus, liquid crystal display device size can be reduced.

Furthermore, based on a reduction in the driving voltage of the drivers in the liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1, one in which electric double layer capacitors that are connected in series to each other, etc., can be used as a battery for supplying power to the drivers (for example, by further stepping up the voltage by using one in which electric double layer capacitors having capacity of 2.5 V are connected in series to one another, the required voltage value can be sufficiently supplied). Thus, liquid crystal

display device size can be further reduced.

In addition, by applying the present invention, reduction in the size of power supply units, such as the liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1 and the battery, and low voltage driving are realized. Thus, the liquid crystal display device including the liquid crystal driving circuit 41 to which the present invention is applied can be used as a display device for use in a small information processing device such as a PDA, a timepiece, and an IC card.

Next, processing of the liquid crystal driving circuit 41 to which the present invention is applied is described with reference to the flowchart in Fig. 12.

In step S1, the controller 51 controls the switch 55 to set GND_r supplied to the row driver 53 to GND, that is, zero volts.

In step S2, the controller 51 controls the switch 54 to set GND_c supplied to the column driver 52 to GND, that is, zero volts.

In step S3, the controller 51 controls the column driver 52 to set the output voltage of the row driver 53 to GND_r.

In step S4, the controller 51 controls the column driver 52 to set the output voltage of the column driver 52 to GND_c.

Processing in steps S1 to S4 supplies zero volts to the transparent column electrodes 12 and the transparent row electrodes 15 corresponding to all the pixel positions of the cholesteric liquid crystal panel. Thus, the potential differences of all inter-pixel electrodes are zero volts.

In step S5, the controller 51 controls the switch 55 to switch GNDr supplied to the row driver 53 from GND to $(V1+V2)$ during a time corresponding to a predetermined pulse width.

10 In step S6, the controller 51 controls the switch 54 to switch GNDc supplied to the column driver 52 from GND to $(-V1-V2)$ during a time corresponding to a predetermined pulse width.

Processing in steps S5 and S6 applies a bipolar pulse voltage of $V1+V2$ to all the pixel electrodes (all the cross points of the transparent column electrodes 12 and the transparent row electrodes 15) in the cholesteric liquid crystal panel 1. Thus, information held before the voltage is applied is reset.

20 In step S7, the controller 51 controls the switches 54 and 55 to set, to GND, GNDr supplied to the row driver 53 and GNDc supplied to the column driver 52.

Processing in step S7 supplies zero volts again to the transparent column electrodes 12 and the transparent row electrodes 15 corresponding to all the pixel positions in

the cholesteric liquid crystal panel 1. Thus, the potential differences of all the inter-pixel electrodes have zero volts again.

In step S8, the controller 51 controls the row driver
5 53 to apply selecting voltage V3 to scan the row electrodes, and controls the column driver 52 to selectively apply inverse-polarity bipolar pulses -V4 to the column electrodes, whereby the cholesteric liquid crystal panel is driven to display information before the process ends.

10 For example, when the voltage is applied to column electrodes Y1 to Yn of the transparent column electrode 12 in the cholesteric liquid crystal panel 1 by the column driver 52, and the voltage is applied to row electrodes X1 to Xm of the transparent row electrode 15 by the row driver
15 53, the bipolar pulse voltages shown in Fig. 11 are applied to the pixel electrodes corresponding to pixels (X1, Y1) to (X3, Y3). Accordingly, after entire planar resetting is performed, among the nine pixels composed of 3 x 3 pixels in the cholesteric liquid crystal panel 1, as shown in Fig. 6,
20 six pixels (X1, Y1), (X1, Y2), (X2, Y2), (X2, Y3), (X3, Y2), and (X3, Y3) are displayed in black and the other pixels are displayed in specified wavelength color.

In the above processing, in the liquid crystal display device using cholesteric liquid crystal capable of holding
25 previously displayed information without being supplied with

power, the inter-electrode potential difference required for performing entire planar resetting by setting the cholesteric liquid crystal in all the inter-pixel-positions to be in the planar state can be generated by switching the
5 voltage values of GNDr and GNDc supplied to the row driver 53 and the column driver 52. The switching of the voltage values of GNDr and GNDc can be performed by using the switches 54 and 55, which are formed by, for example, FETs.

Here, the case of performing bicolor display has been
10 described. However, it is obvious to apply the present invention to the case of performing multicolor display by a liquid crystal display device using cholesteric liquid crystal.

Since, in display of information after entire planar
15 resetting, a method similar to that in a liquid crystal display device of the related art which uses cholesteric liquid crystal is used, the driving voltages required by the row driver 53 and the column driver 52 are determined by the inter-pixel-electrode voltage required for setting the
20 cholesteric liquid crystal to the focal conic state. In other words, in the liquid crystal display device including the liquid crystal driving circuit 41 to which the present invention is applied, each voltage supplied as a driving voltage to the row driver 53 and the column driver 52 can be
25 reduced to approximately half of that in the case of the

related art.

Therefore, according to the liquid crystal display device including the liquid crystal driving circuit 41 to which the present invention is applied, the color of
5 arbitrary pixels can be inverted from a specified wavelength color to black, while suppressing voltages supplied as driving voltages to drivers, and reduced size and cost of a liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1 can be realized.

10 The above-described consecutive processing can be also performed by software. The software is installed from a recording medium to a computer in which programs constituting the software are built in dedicated hardware, or, for example, a multipurpose personal computer or the
15 like in which, by installing various types of programs, various types of functions can be executed.

As shown in Fig. 9, this recording medium includes a package medium which is distributed for providing a program to a user separately for the computer, and which includes a
20 magnetic disk 61 (including a flexible disk), an optical disk 62 (including a CD-ROM (Compact Disk-Read Only Memory) or a DVD (Digital Versatile Disk)), a magneto-optical disk 63 (including an MD (Mini-Disk) (trademark)), or a semiconductor memory 64, in which a program is recorded.

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25 Industrial Applicability

According to the present invention, information can be displayed on a display device using liquid crystal display elements. In particular, resetting of a display on a display unit having cholesteric liquid crystal and writing
5 of information can be performed with a low driving voltage.

In addition, according to another aspect of the present invention, liquid crystal display elements can be driven with a low voltage as well as liquid crystal display elements can be driven.

CLAIMS

1. A display device comprising:

display means in which, by applying voltages to row
electrodes and column electrodes, the state of cholesteric
5 liquid crystal is changed to display information;

a row driver for applying a voltage to the row
electrodes;

a column driver for applying a voltage to the column
electrodes;

10 row-driver-reference-voltage switching means for
selectively switching a first reference voltage supplied to
the row driver between a first voltage having a voltage
value greater than the absolute value of the bipolar voltage
required for setting the state of the cholesteric liquid
15 crystal to a planar state, and a zero volts;

column-driver-reference-voltage switching means for
selectively switching a second reference voltage supplied to
the column driver between a second voltage whose absolute
value is equal to the first voltage and which is reverse in
20 polarity to the first voltage, and zero volts; and

control means for controlling the operation of the row
driver and the column driver, the row-driver-reference-
voltage switching means, and the column-driver-reference-
voltage switching means,

25 wherein:

a driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage;

5 a driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage;

the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to a
10 focal conic state; and

when the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means controls the
15 column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the row electrodes and the second reference voltage is applied to the column
20 electrodes; and

in order to set a desired portion of the cholesteric liquid crystal to the focal conic state, the control means controls the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means to
25 switch each of the first reference voltage and the second

reference voltage to zero volts, and controls the row driver and the column driver to control supply of the first bipolar driving voltage and the second bipolar driving voltage to the cholesteric liquid crystal.

5 2. The display device according to claim 1, wherein:

the row driver is supplied with the first bipolar driving voltage;

the column driver is supplied with the second bipolar
10 driving voltage;

the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which the sum of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage;
15 and

when the control means sets the desired portion of the cholesteric liquid crystal to the focal conic state, the control means controls the row driver to sequentially apply the first bipolar driving voltage so as to scan the row
20 electrodes, and controls the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

3. A display method for a display device
25 comprising a display unit which displays information with

cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the display method including:

5 a first reference-voltage applying step of supplying zero volts as a first reference voltage to a row driver which applies a voltage to the row electrodes, and applying the first reference voltage to the row electrodes;

10 a second reference-voltage applying step of supplying zero volts as a second reference voltage to a column driver which applies a voltage to the column electrodes, and applying the first reference voltage to the row electrodes;

15 a first reference-voltage control step of, in order to set the cholesteric liquid crystal to a planar state, controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value greater than the absolute value of the bipolar driving voltage required for setting the state of the cholesteric liquid crystal to the planar state;

20 a second reference-voltage control step of, in order to set the cholesteric liquid crystal to the planar state, controlling the second reference voltage applied to the column driver to perform switching from zero volts to a second voltage whose absolute value is equal to the first
25 voltage and which is reverse in polarity to the first

voltage;

a third switching step of, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, controlling the first reference voltage applied to
5 the row driver to perform switching from the first voltage to zero volts, and controlling a second driving voltage applied to the column driver to perform switching from the second voltage to zero volts; and

a display control step of, in order to set the desired
10 portion of the cholesteric liquid crystal to the focal conic state, applying a first bipolar driving voltage so as to scan the row electrodes, and selectively applying a second bipolar driving voltage so as to scan the column electrodes, the second bipolar driving voltage having an absolute value
15 equal to the first voltage and being reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes,

wherein:

a driving voltage supplied the row driver is the first
20 bipolar driving voltage, whose absolute value is a third voltage;

a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a forth voltage; and

25 the sum of the third voltage and the fourth voltage is

a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to a focal conic state.

4. A liquid crystal driving circuit for driving
5 liquid crystal display elements including cholesteric liquid crystal, the liquid crystal driving circuit comprising:

a row driver for applying a voltage to row electrodes of the liquid crystal display elements;

a column driver for applying a voltage to column
10 electrodes of the liquid crystal display elements;

row-driver-reference-voltage switching means for selectively switching a first reference voltage supplied to the row driver between a first voltage having a voltage value greater than the absolute value of the bipolar driving
15 voltage required to setting the state of the cholesteric liquid crystal to a planar state, and zero volts;

column-driver-reference-voltage switching means for selectively switching a second reference voltage supplied to the column driver between a second voltage whose absolute
20 value is equal to the first voltage and which is reverse in polarity to the first voltage, and zero volts; and

control means for controlling the operation of the row driver and the column driver, the row-driver-reference-voltage switching means, and the column-driver-reference-
25 voltage switching means,

wherein:

a driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage;

5 a driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage;

the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for
10 setting the state of the cholesteric liquid crystal to a focal conic state; and

when the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference
15 voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the row electrodes and the
20 second reference voltage is applied to the column electrodes; and

in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, the control means controls the row-driver-reference-voltage switching means
25 and the column-driver-reference-voltage switching means to

switch each of the first reference voltage and the second reference voltage to zero volts, and controls the row driver and the column driver to control supply of the first bipolar driving voltage and the second bipolar driving voltage to the cholesteric liquid crystal.

5 5. A liquid crystal driving method for a liquid crystal driving circuit which drives liquid crystal display elements including cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the liquid
10 crystal driving method including:

 a first reference-voltage applying step of supplying zero volts as a first reference voltage to a row driver which applies a voltage to the row electrodes, and applying the first reference voltage to the row electrodes;

15 a second reference-voltage applying step of supplying zero volts as a second reference voltage to a column driver which applies a voltage to the column electrodes, and applying the first reference voltage to the row electrodes;

 a first reference-voltage control step of, in order to
20 set the cholesteric liquid crystal to a planar state, controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value greater than the absolute value of the bipolar driving voltage required for setting
25 the state of the cholesteric liquid crystal to the planar

state;

a second reference-voltage control step of, in order to set the cholesteric liquid crystal to the planar state, controlling the second reference voltage applied to the column driver to perform switching from zero volts to a
5 second voltage whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage;

a third switching step of, in order to set a desired
10 portion of the cholesteric liquid crystal to a focal conic state, controlling the first reference voltage applied to the row driver to perform switching from the first voltage to zero volts, and controlling a second driving voltage applied to the column driver to perform switching from the
15 second voltage to zero volts; and

a driving-voltage-application control step of, in order to set the desired portion of the cholesteric liquid crystal to the focal conic state, controlling sequential application of a first bipolar driving voltage to the row electrodes,
20 and controlling selective application, to the column electrodes, of a second bipolar driving voltage having a voltage value which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes, and whose absolute value is equal to the first
25 voltage,

wherein:

a driving voltage supplied the row driver is the first bipolar driving voltage, whose absolute value is a third voltage;

5 a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a fourth voltage; and

the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for
10 setting the state of the cholesteric liquid crystal to the focal conic state.

6. The display method according to claim 5, wherein the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which
15 the sum of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage.

7. The liquid crystal driving circuit according to claim 6, wherein:

the row driver is supplied with the first bipolar
20 driving voltage;

the column driver is supplied with the second bipolar driving voltage;

the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which
25 the sum of the absolute values of the third voltage and the

fourth voltage is approximately a half of the first voltage;
and

when the control means sets the desired portion of the
cholesteric liquid crystal to the focal conic state, the
5 control means controls the row driver to sequentially apply
the first bipolar driving voltage so as to scan the row
electrodes, and controls the column driver to selectively
apply, to the column electrodes, the second bipolar driving
voltage, which is reverse in polarity to the first bipolar
10 driving voltage applied so as to scan the row electrodes.

8. The liquid crystal driving method according
to claim 7, wherein the first bipolar driving voltage and
the second bipolar driving voltage each have a voltage value
in which the sum of the absolute values of the third voltage
15 and the fourth voltage is approximately a half of the first
voltage.