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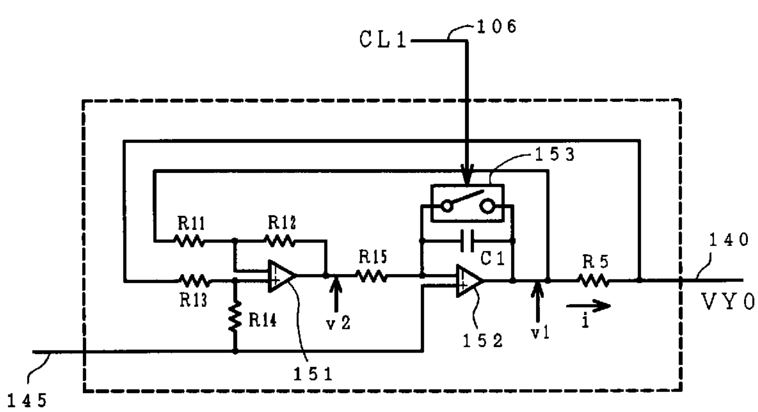
(54) Liquid crystal display having voltage compensating function

(57) The invention relates to a liquid crystal display, and is intended to stabilize the correcting circuit of a simple matrix liquid crystal display for correcting poor picture uniformity that depends on the displayed pattern. The liquid crystal display has non-select voltage lines for scanning electrodes. The correcting circuit detects currents flowing through these non-select voltage lines or voltage variations and adds corresponding voltages to the non-select voltage for the scanning electrodes. The correcting circuit comprises a resistor (R5), an operational amplifier circuit (151), and an integrator circuit (152, C1) for integrating the output from the operational amplifier circuit and resetting the integrated output every subinterval. The resistor is inserted between non-select voltage lines of a power circuit and a scanning electrode driver circuit. Both ends of the resistor are connected to the inverting and non-inverting terminals, respectively, of the operational amplifier circuit. This amplifier circuit has an inverting amplification factor and a non-inverting amplification factor that differ from each other.

FIG. 7



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a liquid crystal display operated at a high frequency and, more particularly, to a simple matrix, high-quality (i.e., high picture uniformity) liquid crystal display in which two or more scanning lines are selected simultaneously. The invention also relates to a liquid crystal display exhibiting fast response, high contrast, and wide viewing angle.

2. Description of the Prior Art

A voltage-averaging method described in "Liquid Crystal Device Handbook", pp. 395-399, has enjoyed wide acceptance as a method of driving liquid crystal displays having a simple matrix liquid crystal panel. With this method, a select scanning voltage is applied to scanning electrodes sequentially for a subinterval, the scanning electrodes corresponding to the rows of the liquid crystal panel. All the scanning electrodes are scanned in one frame. Then, the same operations are repeated. Display electrodes correspond to the columns of the liquid crystal panel. Display voltages which correspond to the values of display data and are higher and lower, respectively, than a non-select scanning voltage level are applied to the display electrodes. Also, the polarity of the voltage applied to the liquid crystal material is inverted at regular intervals, i.e., an alternating operation is performed. The response speed achieved by this voltage-averaging method cannot exceed a limit value.

A method of selecting plural scanning lines has been proposed as a method of driving a liquid crystal display at a response speed exceeding the above-described limit. This method is described in Japanese Patent Examined Publication No. 67628/1994. In this method, a select scanning voltage corresponding to orthogonal functions (e.g., Walsh functions) is sequentially applied to the rows, plural rows at a time. All the scanning electrodes are scanned in one frame. Then, the same operations are repeated. Data voltages corresponding to the number of the values of the orthogonal functions of the selected lines coincident with the values of display data are applied to the data electrodes corresponding to the columns of the liquid crystal panel.

SUMMARY OF THE INVENTION

In recent years, there is an increasing demand for a display device capable of displaying moving pictures in multimedia applications. Where the response speed is increased by the prior art voltage-averaging method, contrast drop and flicker are induced due to the limited frame response. Furthermore, crosstalks produced by some picture patterns result in shadow effects. A method of driving plural scanning lines at the same time as described later has been recommended to decrease these contrast drop and flicker.

Various methods have been proposed to reduce the shadow effects due to limited frame response:

1) The periodicity of the contents of a picture displayed is qualitatively extracted. The waveform either of the scanning voltage or the signal voltage is corrected according to the amount of periodicity extracted. This method is disclosed, for example, in Japanese Unexamined Publication No. 89/1990.

2) An electrical current flowing through the signal line electrodes is detected. A voltage corresponding to the detected current is fed back to the scanning electrodes. This method is described, for example, in Japanese Patent Unexamined Publication No. 100639/1993.

3) A voltage is taken from the signal voltage itself either via a capacitor or via an electrical resistor. This voltage is amplified via an operational amplifier and added to the scanning voltage. This method is described, for example, in Japanese Patent Unexamined Publication No. 12030/1994.

The method of driving plural scanning lines at the same time as described above can, in principle, reduce the contrast drop due to limited frame response, but shadow effects, or poor picture uniformity, are more conspicuous when certain patterns are displayed than in the voltage-averaging method. This nonuniformity is observed both vertically and laterally.

Of these picture nonuniformities, vertical nonuniformities produced at the top and bottom of each vertical ruled line drawn against a totally black background are particularly conspicuous and have presented problems. These vertical shadow effects are caused by the fact that the effective value of the voltage applied to the liquid crystal material varies among individual rows. In particular, as the data voltage changes, spike-like distortions, or crosstalks, are produced on the scanning voltage. The effects of the crosstalk differ among the individual rows, thus giving rise to the aforementioned effective value variations. For example, where a black vertical ruled line (an OFF region) as shown in Fig. 16A is to be displayed, a liquid crystal material interposed between data and scanning electrodes as shown in Fig. 16C can be regarded as an equivalent circuit of a resistor R and a capacitor C which correspond to the resistance of each electrode and the capacitance of the liquid crystal material, respectively. An electrical current flows in the direction indicated by the arrow, thus inducing a voltage drop. Therefore, when data voltages on the background (an ON region) are all varied in the same direction, as shown in Fig. 16B, the effective voltage increases in the ruled line portions. Conversely, on the background, the effective voltage decreases. That is, the non-select scanning voltage is distorted. Accordingly, point A on the ruled line looks brighter and more transparent than point B on the background shown in Fig. 16A though both are turned ON. The phenomenon described thus far is the main cause of the vertical shadow effects, and is induced by waveform distortion of the non-select voltage applied to the scanning electrodes, the distortion being brought about by the fact that the effective value of the voltage applied to the liquid crystal material is different among rows.

Where horizontal rules lines, or OFF regions, as shown in Fig. 17A are displayed, the capacitance C of the liquid crystal material layer depends on its dielectric constant as shown in Fig. 17B. Generally, activated regions of a liquid crystal material have a higher dielectric constant, while unactivated regions exhibit a lower dielectric constant. These two kinds of regions differ in effective time constant. Therefore, the waveform of the select scanning voltage applied to the scanning lines meeting numerous activated regions of the background is distorted as shown in Fig. 17C. Consequently, the effective values of columns meeting many activated regions are lower than those of rows meeting many unactivated regions. As a result, point B on the background of Fig. 17A looks darker by an amount corresponding to the effective value decrease than point A at a row across a ruled portion although both are in ON state. This phenomenon is the main cause of lateral picture nonuniformity, or shadow effects, and is brought about by the fact that the waveform of the select voltage applied to the scanning electrodes is distorted, which in turn is produced because the effective value of the voltage applied to the liquid crystal material differs among rows.

Several methods are available to correct conspicuous shadow effects produced by adoption of the method of selecting plural scanning lines simultaneously as described above. That is,

1) Changes in voltage or current of the voltage on the signal electrodes are monitored to estimate the distortion of the waveform of voltage between scanning and signal electrodes. A correcting voltage is superimposed on the waveform of the driving voltage to counteract the distortion. This technique is described, for example, in Japanese Unexamined Patent Publication No. 27899/1994.

2) The voltage applied to each scanning electrode is taken and fed to the preceding stage of signal driver circuit to make a correction. That is, feedforward control is provided. This method is described, for example, in Japanese Unexamined Patent Publication No. 129128/1995.

3) Row signals are produced successively with high periodicity. For this purpose, the sequence of column vectors of a selected matrix is determined. An orthogonal matrix system best adapted for crosstalk reduction is used. This technique is described, for example, in Japanese Patent Unexamined Publication No. 160390/1996.

4) One frame period is divided into plural virtual block periods. During each block period, the select period is divided into *n* select subintervals which are regularly spaced from each other. A select voltage is applied every select subinterval. This technique is described, for example, in Japanese Patent Unexamined Publication No. 15556/1997.

In the prior art method for reducing the shadow effects produced at the top and bottom of each vertical ruled line, the waveform distortion is estimated from the waveform of the voltage applied to the signal electrodes. A corresponding correcting voltage is superimposed on the voltage applied to the scanning electrodes. Since the waveform is not directly sensed, it has been impossible to make a precise correction. In the conventional method consisting of directly sensing the waveform distortion on the scanning electrodes and applying a correcting voltage directly to the scanning electrodes, the correcting voltage itself distorts the waveform of the voltage, making the scanning voltage unstable. As a result, flicker is induced, or sufficient correction is not made. That is, in the prior art techniques for correcting shadow effects, the correcting waveform acts to amplify the current that is a cause of a distortion. That is, positive feedback is provided for an electrical current. In an actual circuit, the scanning voltage is unstable, producing flicker, or sufficient correction is not obtained.

The shadow effects produced at the top and bottom of each vertical ruled line differ in principle of production from the shadow effects produced sideways. Furthermore, their respective distortions are mainly produced on the non-select and select voltages, respectively, of the scanning voltage. Therefore, using the same correcting method to reduce these two kinds of shadow effects may be inappropriate or impossible to achieve.

To display moving pictures at a frame frequency of 150-300 Hz or more, the above-described method of driving the liquid crystal display must be improved further. Furthermore, a liquid crystal material operating at a high response speed of from 150 to 80 ms or less must be used. In addition, the used optical members must be optimally combined to accommodate the narrowed cell gap of the liquid crystal display. Moreover, a contrivance is needed to compensate for a contrast decrease due to correction made for reductions of shadow effects. The prior art technique has made no suggestions for finding a combination to solve all of these requirements.

Accordingly, it is a first object of the present invention to provide a liquid crystal display showing high quality image. Especially that liquid crystal display havs an electric circuit that is stable in operation and capable of sufficiently correcting shadow effects, as well as a method of driving this liquid crystal display.

It is a second object of the invention to provide a liquid crystal display in which different kinds of picture nonuniformity produced for different causes are reduced by different methods, as well as a method of driving this liquid crystal display.

The first object is achieved in accordance with the teachings of the invention by a following liquid crystal display comprising a pair of electrode substrates having scanning and data electrodes that intersect each other such that dots are formed at intersections of these scanning and data electrodes,

a scanning electrode driver circuit for applying a non-select voltage or a select voltage to said scanning electrodes during a given subinterval,
a data electrode driver circuit for applying a signal voltage to said data electrode according to data about a picture to be displayed; and
a power circuit for supplying the non-select voltage and the select voltage to said sacanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit comprising a resistor used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier circuit for amplifying the detected electrical current, and a correcting voltage-generating circuit for applying the non-select voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on a reference voltage to said scanning electrode driver circuit, said correcting voltage-generating circuit having a function of resetting the output from said operational amplifier circuit every subinterval.

The waveform distortion on a scanning electrode during non-select period occors at every subinterval(one time divisional period) or every plural subinterval because of contents of image to be displayed. Therefore, it is the most preferbale to reset amplified amount at every subinterval. However, of course, it is possible to modify so that the voltage generating circuit reset or restore that.

To reduce noise effects and optimize the correcting characteristics, it is desired to place a signal modulator circuit between the operational amplifier circuit and the correcting voltage-generating circuit. The signal modulator circuit consists of a pair of bidirectional diodes.

In order to prevent the amount of integration obtained by directly integrating transient distortion from becoming larger than the optimum amount of correction, a limiter circuit consisting of a pair of bidirectional diodes is preferably disposed between the source of the given reference voltage and the operational amplifier circuit output.

The second object described above is achieved by a liquid crystal display comprising scanning and data electrodes that intersect each other,

a pair of substrates oppsing each other via liquid crystal layer,
a scanning electrode driver circuit for applying a non-select voltage or a select voltage to said scanning electrodes during a predetermined time interval,
a data electrode driver circuit for applying a signal voltage to said data electrode according to data about a picture to be displayed;
a correcting clock signal generating circuit generating a pulse signal accoding to contents of a picture to be displayed; and
a power circuit for supplying the non-select voltage and the select voltage to said sacanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit supplying a voltage superinposed a compensating voltage according to an electrical current in a scanning electrode while non-selected period on a first reference vaoltage as the non-select voltage,
said scanning electrode driver circuit supplying a voltage superimposed a compensating voltage according to said pulse signal on a second reference voltage as said select voltage.

The novel liquid crystal display achieving the first and second objects described above are especially advantageous in driving the display by selecting plural scanning lines simultaneously. In this case, the select voltages or the non-select voltage corresponding to given orthogonal functions are sequentially applied to the scanning electrodes. The signal electrode driver circuit applies a signal voltage corresponding to the orthogonal functions and to the contents of the displayed picture to the signal electrodes.

The aforementioned operational amplifier circuit preferably includes an operational amplifier device having inverting and non-inverting terminals to which the ends of the resistor are respectively connected, the resistor being used to detect the electrical current flowing into the scanning electrode. The operational amplifier device has an inverting amplification factor and a non-inverting amplification factor that differ from each other.

The liquid crystal display in which a voltage correction is made to reduce shadow effects preferably uses a liquid crystal material having a low viscosity of approximately 20 mPa • s (preferably less than 15 mPa • s, more preferably less than 13 mPa • s), colored beads providing good light shielding, and phase-difference films exhibiting steep wavelength-dispersing characteristics in combination to provide high response, high contrast, and wide viewing angle.

The foregoing and other objects, advantages, manner of operation and novel features of the present invention will be understood from the following detailed description when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a waveform diagram of power circuit output, scanning voltage, and data voltage used in Embodiment 1 of a liquid crystal display in accordance with the present invention;
Fig. 2 is a diagram illustrating the relation between a voltage applied to one scanning line (Y1) of Fig. 1 and a line clock signal CL1;
Fig. 3 is a block diagram of a liquid crystal display according to Embodiment 1 of the invention;
Fig. 4 is a diagram illustrating the general operation of a scanning electrode driver circuit shown in Fig. 3;
Fig. 5 is a diagram illustrating the general operation of a data electrode driver circuit shown in Fig. 3;
Fig. 6 is a diagram of a power circuit shown in Fig. 3;
Fig. 7 is a circuit diagram of one example of a voltage-correcting circuit shown in Fig. 6;
Fig. 8 is a block diagram of a power circuit according to Embodiment 2 of the invention;
Fig. 9A is a circuit diagram of one example of a signal modulator circuit shown in Fig. 8;
Fig. 9B is a circuit diagram of a voltage-correcting circuit incorporating a signal modulator circuit;
Fig. 10 is a circuit diagram of a voltage-correcting circuit according to Embodiment 3 of the invention, and in which a limiter circuit is incorporated;
Fig. 11 is a diagram illustrating power circuit output, scanning voltage, and data voltage in a liquid crystal display according to Embodiment 4 of the invention having a function of correcting select voltages applied to scanning electrodes;
Fig. 12 is a diagram illustrating the relation among a correcting pulse (CC2), a voltage applied to one scanning line (Y2), and a line clock signal CL1 shown in Fig. 11;
Fig. 13 is a block diagram of a liquid crystal display according to Embodiment 4 of the invention;
Fig. 14 is a block diagram of a power circuit shown in Fig. 13;
Fig. 15 is a diagram illustrating scanning voltages applied to one scanning electrode for separate select periods;
Figs. 16A, 16B, and 16C are diagrams illustrating the principle on which shadow effects are produced at top and bottom of a vertical ruled line;
Figs. 17A, 17B, and 17C are diagrams illustrating the principle on which shadow effects are produced at sides of a horizontal ruled line;
Fig. 18 is a diagram illustrating the positional relation between optical members in a liquid crystal display according to the invention;
Fig. 19 is a diagram illustrating the relation of adjacent rubbing directions and an optical axis in the optical arrangement of a liquid crystal display according to the invention; and
Fig. 20 is a diagram illustrating the relations among the wavelength dispersion characteristics of 4 kinds of phase-difference film.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

EMBODIMENT 1

An embodiment of the present invention is next described by referring to Figs. 1-7. In this embodiment, the number of lines selected simultaneously is two. Fig. 1 is a timing diagram of the output from a power circuit in one embodiment of the invention and voltages applied to the liquid crystal panel, illustrating a state in which vertically successive dots are activated to display ruled lines against a totally unactivated background. The power circuit produces a voltage VY0 to a scanning driver circuit. A correcting voltage is added to the voltage VY0 according to the current flowing on the sacanning line during non-scanned(non-selected) period and thus the output voltage VY0 varies.

As a result, the output from the scanning electrode driver circuit takes waveforms Y1-Y4. During non-select period of the scanning voltage, a pulse-like waveform distortion is produced due to transition of the background data voltage waveform. Immediately after the waveform distortion, a correcting voltage is applied to cancel out the distortion. The correcting voltage is reset at the end of the subinterval. The timing of one subinterval is controlled by a line clock pulse signal CL1 consisting of clock pulses having a given pulse width as shown in Fig. 2. As can be seen from this figure, each subinterval starts at the trailing edge of each line clock pulse CL1. The resetting of the correcting voltage is started at the leading edge of each line clock pulse CL1. In Fig. 2, the pulse width of the line clock pulses CL1 is drawn in exaggerated size relative to one subinterval. Preferably, the pulse width is long enough to permit the correcting voltage to reset itself almost completely.

One example of liquid crystal display for achieving this driving method is now described by referring to Figs. 3-7. Fig. 3 is a block diagram showing the structure of the liquid crystal display. Shown in this figure are a liquid crystal panel 101, a scanning electrode driver circuit 102 for selecting two lines simultaneously, and a data electrode driver circuit 103 for selecting the state of the two lines selected by the scanning electrode driver circuit 102. Eight-bit parallel data items D7-D0 are display data 104 about a displayed picture. A data latch clock pulse CL2 (105) is synchronized to the display data 104. A data latch clock pulse CL2 is synchronized to the display data 104. One line of data is sent during one period of line clock pulse 106. The duration of a leading line clock pulse FLM determines 1 frame period. When a display off control signal DISPOFF is at level 0, the display is halted. These display data and synchronising signals 104-108 are supplied from a liquid crystal controller 109. Power voltages 115 and 116 are necessary for the data voltage driver circuit and the scanning driver circuit, respectively, and are generated by a power circuit 114. The power voltages 115 and 116 are based on an external power voltage 111 (VCC) and ground 112 (GND), respectively. A voltage 113 (VCON) adjusts the voltage levels of liquid-driving voltages. In the present embodiment, the voltage VCON is supplied from the body 110 of the display system. Signals 117 and 118 representing orthogonal functions W1 and W2, respectively, are produced by the scanning electrode driver circuit 102. The operation of each block of the liquid crystal display shown in Fig. 3 is next described by referring to Figs. 4-9.

The principle of operation of the scanning electrode driver circuit 102 in accordance with the present invention is first described by referring to the diagram of Fig. 4. The scanning electrode driver circuit 102 receives an FLM signal 107 and the clock pulse signal CL1 (106) and produces a line-selecting signal for sequentially addressing two lines to be selected and two-bit signals 117 and 118 representing orthogonal functions W1 and W2, respectively. According to the combination of the line-selecting signals and the orthogonal functions, a scanning voltage as shown in Fig. 4 is selected and applied to the liquid crystal panel 101 via scanning electrodes. In particular, if the orthogonal functions are 0, and if the line-selecting signal is in "scan state" (state 1) as shown in Fig. 4, voltage VYL is selected. If the line-selecting signal is in "non-scan state" (state 0), voltage VY0 is selected. If the orthogonal functions are 1, and if the line-selecting signal is in "scan state" (state 1), then voltage VYH is selected. If the line-selecting signal is in "non-scan" state, voltage VY0 is selected. If the display off control signal DISPOFF 108 is 0, all line-selecting signals are unselected (state 0). Voltage VY0 is produced.

The principle of operation of the data electrode driver circuit 103 in accordance with the present invention is next described by referring to Fig. 5. The data electrode driver circuit 103 accepts the display data 104 as a clock signal CL2 (105), and has a line data latch circuit for holding 2 lines of accepted data for 2 horizontal periods. Two lines of display data are simultaneously read from the line data latch circuit and compared with the two-bit signals 117 and 118 representing orthogonal functions W1 and W2, respectively, supplied from the scanning electrode driver circuit 102. The driver circuit 103 determines the level of the voltage applied to the data electrode according to the results of the comparison. More specifically, as shown in Fig. 5, coincidence circuits compare outputs LD1 and LD2 from the line data latches with the values of the signals 117 and 118 representing the orthogonal functions W1 and W2, respectively. The number of voltages of level 1 is selected from the three-level liquid crystal-driving data voltages according to the number of coincidence, and a signal indicating the result is delivered. For example, if the number of coincidence is 0, voltage VX2 is selected. If the number of coincidence is 1, voltage VX1 is selected. If the number of coincidence is 2, voltage VX0 is selected. If the display off control signal DISPOFF 108 is 0, voltage VX1 is urged to be selected.

One example of the power circuit 114 in accordance with the present invention is next described by referring to Figs. 6-9. Fig. 6 is a diagram of the power circuit 114. Figs. 7-9 are circuit diagrams of a voltage-correcting circuit incorporated in the power circuit 114. As shown in Fig. 6, this power circuit 114 comprises a DC-DC converter 130 driven with voltage VCC (111), voltage-dividing resistors R1-R4, operational amplifiers 131-134, and a voltage-correcting circuit 135. The voltage-correcting circuit is composed of a current-detecting resistor R5, an operational amplifier circuit 136, an integrator circuit 137, and a correcting voltage-generating circuit 138. A positive select voltage VYH (139), a non-select voltage VY0 (140), and a negative select voltage VYL (141) are used to drive the scanning electrodes. These voltages 139-141 are parts of the power voltages 116 shown in Fig. 3 and applied to the scanning electrode driver circuit 102. Data voltages VX0-VX2 (142, 143, 144) which are parts of the power voltages 115 shown in Fig. 3 are used to drive the liquid crystal, and are applied to the data electrode driver circuit 103. A reference voltage 145 is employed to generate the voltages VY0 and VX1 (140).

The voltages VYH and VYL (139 and 141) are directly generated by the DC-DC converter 130 and can be adjusted with an adjusting voltage VCON 113. Voltages VX2 (142), VX0 (143), and the reference voltage 145 are stepped down with resistors R1-R4 between the scanning driver power voltage VYH (139) and the voltage VYL (141). The resulting voltages are delivered after their impedances are transformed via a voltage follower circuit using operational amplifiers

131-133. The voltage VX1 (143) is delivered from the reference voltage 145 via an additional voltage follower circuit. The resistances R1-R4 have the following relations:

$$R1 = R4$$

and

$$R2 = R3$$

The voltages described above have the following relationships:

$$VYH > VY0 > VYL$$

$$VYH - VY0 \fallingdotseq VY0 - VYL$$

$$VX2 > VX1 > VX0$$

$$VX2 - VX1 = VX1 - VX0$$

The voltage VY0 (140) is created from the reference voltage 145, using the clock pulse signal CL1 (106), by the voltage-correcting circuit 135.

Fig. 7 shows one example of the voltage-correcting circuit 135. A resistor R5 is used to detect an electrical current, and is inserted in series with the non-select voltage line for driving the scanning electrodes. At non-selected locations, distortion of the waveform of the signal driving the scanning electrodes is produced by a voltage drop across the circuit resistance, which in turn is induced by an electrical current flowing through the scanning electrodes due to crosstalk during transition of the data voltage. The current flowing through the scanning electrodes can be forecasted from the current flowing through the power circuit. Therefore, the distortion of the waveform at the non-selected portions can be forecasted from the value of the current flowing through non-selected lines of the power circuit for driving the scanning electrodes. That is, a voltage developed across the resistor R5 is detected, so that the distortion of the waveform of the signal driving the scanning electrodes at the non-selected portions can be detected.

An operational amplifier circuit is composed of resistors R11-R14 and an operational amplifier 151. The terminal of the resistor R5 on the side of the scanning electrode driver circuit is connected with the resistor R13 on the non-inverting amplification side of the operational amplifier circuit. The terminal of the resistor R5 on the side of the power circuit is connected with the resistor R11 on the non-inverting amplification side of the operational amplifier. The inverting amplification factor is given by

$$A = R12 / R11$$

The non-inverting amplification factor is given by

$$B = R14 (R11 + R12) / (R11 (R13 + R14))$$

An inverting integrator circuit is formed by a resistor R15, a capacitor C1, an operational amplifier 152, and a switch 153 that turns on and off in response to the clock signal CL1. In the present circuit, the integrator circuit acts also as a correcting voltage-generating circuit. The operation of the circuit shown in Fig. 7 is next described.

When current i is not produced from the output, i.e., no waveform distortion takes place, the output voltage VY0 is the same as the reference voltage 145. Let v1 be the output voltage from the integrator circuit. When the current i is produced, the output voltage v2 from the operational amplifier circuit is given by

$$\begin{aligned} v2 &= - A \cdot v1 + B \cdot (v1 - i \cdot R5) \\ &= - B \cdot R5 \cdot i + (B - A) \cdot v1 \end{aligned}$$

provided that the reference voltage 145 is 0 V. The output v1 from the integrator circuit is given by

$$v1 = B \cdot D \cdot R5 \cdot \int i\, dt - (B - A) \cdot \int v1\, dt$$

where $D = C1 / R15$.

A method of making a correction, using the relation $A = B$, without performing integration may be conceivable. That is, v1 = K • i . With this method, the correction is made according to the current value. However, where the load on the liquid crystal panel is considered, the current i changes in an increasing direction when the output voltage v1 varies. Therefore, if full correction is made, an infinitely large current is necessary in principle. In practice, sufficient correction is not made, or the circuit is unstable. A conceivable countermeasure against them is described in the above-cited Japanese Unexamined Patent Publication No. 27899/1994, where data voltage is corrected. Another conceivable countermeasure is to use time-delay elements. However, the former method has the disadvantage that the displayed picture flickers. The latter method has the disadvantage that the circuit is complicated.

Accordingly, in the present invention, integration of the current value is used for correction to produce time delay effects and to lower the corrected voltage. Since the current varies among subintervals, it is necessary to reset the integrated value every subinterval. A term for suppressing variations in the output voltage v1 is inserted by establishing the relation $A < B$ $(A \neq B)$. In this way, the operation of the circuit is stabilized. Thus, sufficient correction is made stably.

The above mentioned method so that the correctiong voltage generating circuit resets amplified value every subinterval is the most prefarable embodiment for simplifying circuit and the other reason. It is possible to modify so that the amplified value charged in capacitance C1 is leaked every plural subinterval according to an occorance raitio depending to displayed pattern and orthogonal function

EMBODIMENT 2

A liquid crystal display, forming Embodiment 2 of the present invention, is next described by referring to Fig. 8. In this Embodiment 2, signal modulation means are added to the correcting circuit to remove noise effects in the circuit or to optimize the correcting characteristics. Fig. 8 shows a power circuit in accordance with Embodiment 2. A signal modulator circuit 146 is interposed between an operational amplifier circuit 136 and an integrator circuit 137. One example of the signal modulation circuit is shown in Figs. 9A and 9B, where the signal modulator circuit 146 is made of a bidirectional diode. Thus, the integrator circuit is not set into operation unless a voltage exceeding the forward voltage of the diode is applied. Consequently, correction can be made without detecting noises in the circuit. Where shadow effects occurring at top and bottom of each vertical ruled line are corrected, the appropriate amount of correction strictly differs between the case where a black ruled line exists against a white background and the case where a white ruled line is present against a black background, because the dielectric constant differs. However, where the correcting voltage is generated fundamentally by detecting currents on the scanning electrodes, it is difficult to vary the amount of correction according to whether the background is white or black. The signal modulator circuit 146 gives a threshold value in correcting the integration. As a result, the amount of correction can be optimized approximately.

In Embodiments 1 and 2, the voltages VY0 and VX1 are separated. The voltage output VX1 may be taken from the voltage output VY0. A current amplification circuit may also be added as a load to the output of the integrator circuit.

The signals 117 and 118 representing the orthogonal functions W1 and W2, respectively, in accordance with the invention are produced within the scanning driver to drive the display device. The invention is not limited to this scheme. If these signals are generated outside the scanning driver, and if the orthogonal functions are given to the scanning driver and the data driver, no problems will take place. Furthermore, this may be combined with the above-described power circuit into a single driver IC. In addition, in Embodiments 1 and 2, the number of lines selected simultaneously is 2. The number is not limited to two. Similar advantages can be derived where the number is other than two.

EMBODIMENT 3

Embodiment 3 of the present invention is next described by referring to Fig. 10. In the configuration of Embodiments 1 and 2, transient waveform distortions are detected. Therefore, the calculated analog correcting voltage may become excessive compared with appropriate values. Depending on the displayed pattern, the shadow effect-reducing effect may be halved.

In the present embodiment, as shown in Fig. 10, a pair of bidirectional Schottky diodes 147 are inserted between a stepped-down voltage 145 (reference voltage) for a non-select voltage and the output of the signal modulator circuit 146 or the operational amplifier 151 of the operational amplifier circuit 136. They are connected to an intermediate point between two resistors R16 and R17. This limits the current flowing into the integrator circuit 137 to within the ratio VF/R17, where VF is the threshold voltage of the Schottky diodes 147 and R17 is the resistance value of the resistor R17. Hence, overcompensation due to transient currents can be suppressed.

EMBODIMENT 4

An embodiment having a function of correcting the select voltage on the scanning electrodes as well as the functions of Embodiments 1, 2, and 3 described above is now described by referring to Figs. 11-14.

As described previously in connection with Fig. 17, if black pixels (OFF state) are concentrated in the second scanning line (Y2) and the third scanning line (Y3) so that ruled lines are displayed against a white (ON state) background, the liquid crystal material shows a small dielectric constant on these second and third scanning lines. Therefore, the time constant is small and the waveform is distorted only a little. Accordingly, in order to bring white portions (such as point A in Fig. 17A) located on both sides of each horizontal ruled line into locations (such as point B in Fig. 17A) where the liquid crystal material exhibits a high dielectric constant against a white background so that the time constant is increased and a decreased effective value results, given voltages VYHA and VYLA closer to the reference voltage VY0 than the original select voltages VYH and VYL are applied as select voltages. The pulse widths of these applied voltages represent the contents of the displayed picture. These pulse widths are determined by correcting pulses CC1 and CC2. When the select pulses are being applied, the scanning electrode driver circuit selectively supplies given voltages VYHA or VYLA closer to the reference voltage VY0 to the scanning electrodes instead of the original select voltages VYH or VYL.

The pulse widths of the correcting pulses CC1 and CC2 are controlled according to the contents of a displayed picture on each row represented by the data signal. As shown in Fig. 12, the effective value is corrected by the selectively applied given voltages VYHA or VYLA instead of the original select voltages VYH or VYL during the periods of these pulses. Therefore, it differs in nature from one subinterval that is a fraction of the period of the system clock pulse or from the line clock pulse CL1 having a given pulse width.

Because of the correction described above, the effective values of the white pixels located on both sides of each horizontal ruled line can be made to match the effective value of the white background. As a result, picture nonuniformities decrease. A liquid crystal display operating in this way is shown in the block diagram of Fig. 13, where a correcting clock-generating circuit 148 is placed in addition to the circuitry described in Embodiments 1-3, as shown in Fig. 13. The correcting clock-generating circuit 148 receives some D2-D0 (or D7-D0) of the display data signals from the liquid crystal controller 109, data clock signal CL2, line clock signal CL1, and a frame sync signal FLM, counts the number of display data items on each line indicating whether each pixel is ON or OFF, and delivers correcting pulses CC1 and CC2 according to the obtained count. If the number of scanning lines selected simultaneously is n, n kinds of correcting pulses CC1-CCn are delivered.

Each scanning driver circuit selects either one or both of first select voltage VYH, VYL or second select voltage VYHA, VHLA of the power voltages from the power circuit shown in Fig. 14, depending on whether any correcting pulses are present or absent. One conceivable method of bringing the effective values of the white pixels on both sides of each horizontal ruled line into agreement with the effective value of the white background is to apply correcting voltages so as to reduce the effective value when waveform distortion is produced. In this case, a voltage higher than VYH is produced as the power voltage. Therefore, where select voltages are corrected, it is desired to accommodate portions whose effective values have not decreased to those portions whose effective values have decreased, as in the present embodiment. Embodiments 1-3 are arbitrarily combined to constitute the voltage-correcting circuit.

In Embodiments 1-4, the number of scanning lines selected simultaneously is 2, and the select periods are continuous with each other. As shown in Fig. 15, a method of separating select periods is also adopted to thereby reduce horizontal picture nonuniformities further. Especially, a so-called 2 line selection-6 line shift method (i.e., select periods are separated as shown in Fig. 15, and orthogonal functions are completed every 6 scanning line) is optimal from the viewpoint of the storage capacity of memory incorporated in the driver circuit and the driving voltage. Preferably, this method is combined with Embodiments 1-4 described above.

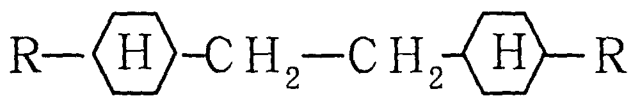
EMBODIMENT 5

Where moving pictures are required to be displayed at a frame frequency of about 150 Hz (ideally, up to approximately 300 Hz), which is higher than the conventional frequency of 80 Hz, the liquid crystal display must be operated by the improved methods described in Embodiments 1-4. Furthermore, a liquid crystal material operating at a high response speed of less than 150 ms or less (ideally up to about 80 ms) must be used. In addition, the used optical members must be optimally combined to accommodate the narrowed cell gap of the liquid crystal display. Moreover, it is necessary to compensate for a contrast decrease due to correction for reductions of shadow effects. In realizing high-speed operation of the driven surface, selecting an optimum liquid crystal material is important for commercial products. Heretofore, liquid crystal materials operating at high speeds have been developed.

Generally, in achieving an STN liquid crystal, it is important to minimize the viscosity (η) and the liquid crystal layer thickness (cell gap d) so that the product of the refractive index anisotropy (Δn) of the liquid crystal material and the thickness d of the liquid crystal layer is about 0.8 to 0.9 μm, as described in "Next-Generation Liquid-Crystal Display Techniques", Industrial Research Society of Japan, November 11, 1994, pp. 136-138.

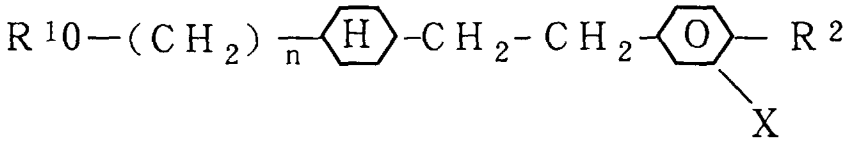
The response time (τ) of a liquid crystal is generally proportional to ηd^2. However, the interface of the orientation film of the liquid crystal layer may be known as a stationary layer and thus some of the interface does not contribute to electrochemical changes. For this and other reasons, where the cell gap is reduced to about 4 μm, no proportional relation holds. This forces the viscosity of the liquid crystal material to be reduced. Furthermore, the liquid crystal layer thickness, or the cell gap d, cannot be reduced below about 4 μm because of fabrication difficulties. Because of the limitation imposed by the response speed, the thickness cannot be increased over 7 μm. In practical applications, the cell gap is preferably set to 5 to 6 μm. Where a liquid crystal material of low viscosity is combined with the driver circuit of Embodiments 1-4 described above, multiplied effects are produced. As a result, a high-quality, high-response liquid crystal display can be accomplished.

A liquid crystal material satisfying the above-described requirements is obtained by adding a viscosity-reducing agent to an ordinary liquid crystal. One example of this viscosity-reducing agent is a low-viscosity liquid crystal described in Japanese Patent Unexamined Publication No. 11386/1984 and given by the general formula



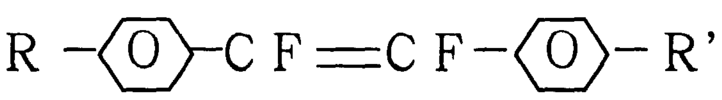
(1)

Another example is prepared by adding a low-viscosity liquid crystal described in Japanese Patent Unexamined Publication No. 235935/1992 and given by the general formula



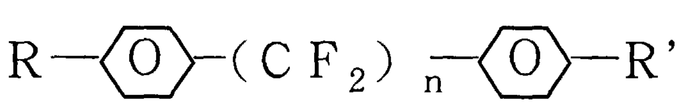
(2)

One example of a liquid crystal material having a large product Δn and a low viscosity includes a difluorostilbene-based liquid crystal, as described in the above-cited "Next-Generation Liquid-Crystal Display Techniques", 16th Liquid Crystal Discussion Meeting Data (1990, October 2, 3L304), 18th Liquid Crystal Discussion Meeting Data (1993, October 2, 2D13), Japanese Patent Unexamined Publication No. 329566/1994, Japanese Patent Unexamined Publication No. 126199/199995, and Japanese Patent Unexamined Publication No. 259478/1996. The general formula of the difluorostilbene-based liquid crystal is given by



(3)

Japanese Patent Unexamined Publication Nos. 51332/1993, 170679/1993, 208925/1993, 279287/1993, and 331084/1993, describe mixed liquid crystal materials that have low viscosities and are stable against light and include liquid crystals given by the general formula



(4)

The low-viscosity mixed liquid crystals described above have viscosities of less than 20 mPa・s at 20°C and are preferably combined with any of the driver circuits of Embodiments 1-4 operating at response speeds of less than about 150 ms. Especially, where a cell gap of about 5 to 6 μm is adopted in practical applications, the used liquid crystal material includes a low-viscosity liquid crystal material defined in terms of Chemical Formula (3) or (4) above. Preferably, the viscosity of the finished liquid crystal material at 20°C is less than 15 mPa・s, more preferably 13 mPa・s. Where the cell gap is set to about 6 μm, a low-viscosity liquid crystal material defined in terms of Chemical Formula (3) or (4) above is preferably added so that the viscosity of the finished liquid crystal material at 20°C is less than 13 mPa・s.

The response speed can be increased to some extent by reducing the viscosity of the liquid crystal. Where the response speed is increased by narrowing the cell gap, a liquid crystal material having large refractive index anisotropy is necessary to set the aforementioned product Δnd, or retardation, to within the range of from 0.8 to 0.9 μm.

However, such liquid crystals generally have large wavelength dependence. That is, the color tone is varied according to the viewing angle. Also, brightness variations are conspicuous at shorter wavelengths. In practical applications, this makes it essential to adopt a phase-difference film whose retardation Δnd (wavelength dispersion characteristics) depends heavily on wavelengths.

Fig. 18 shows the optical arrangement of a liquid crystal display in accordance with the present invention. A liquid crystal layer material layer fills the space between a top substrate 30 and a bottom substrate 31. The space defines a cell gap of *d*. A pair of phase-difference films 34, 35 and a pair of polarizing sheets are disposed on opposite sides of the cell defined by the top and bottom substrates 30 and 31, respectively.

An orientation film consisting of a polymer layer is positioned at each interface between the liquid crystal material layer and the top and bottom substrates. To define the twist angle θ of the liquid crystal molecules, their rubbing directions 40 and 41 are determined as shown. As shown in Fig. 19, the rubbing directions are horizontally symmetrical with respect to the liquid crystal panel. The twist angle θ is 230 to 260 degrees. The optical axes 44 and 45 of the phase-difference films 34 and 35, respectively, form angles α and γ, respectively, of 40 to 90 degrees (preferably, 70 to 90 degrees) with respect to their respective adjacent rubbing directions 40 and 41. The axes of polarization 42 and 43 of the polarizing sheets 32 and 33, respectively, make angles β and δ, respectively, of 20 to 70 degrees (preferably, 30 to 60 degrees) with respect to the optical axes 44 and 45 of their respective adjacent phase-difference films 34 and 35.

Materials that have various wavelength dispersion characteristics and can be used for the phase-difference films are known as described in the above-cited "Next-Generation Liquid-Crystal Display Techniques", pp. 131-132.

A three-wavelength light source having three strong wavelengths of about 450 nm, 550 nm, and 630 nm is used for a backlighting arrangement for the liquid crystal display. In Embodiments 1-4 described above, where the cell gap d is set to 4 to 6 μm, phase-difference films preferably exhibit such characteristics that the products Δn at center wavelengths of approximately 550, 450, and 630 nm are approximately 1.0, 1.1, and 0.97, respectively.

Fig. 20 is a diagram showing the wavelength dispersion characteristics of PVA (polyvinylalcohol), PMMA (methyl polymethacrylate), PC (polycarbonate), and PSF (polysulfone). The aforementioned requirements are satisfied to some extent by fabricating at least one of the two phase-difference films from PSF and fabricating the other from PC. Alternatively, both are made from PSF.

We have confirmed that, where the cell gap d of the liquid crystal display is about 6 to 7 μm, if two phase-difference films having wavelength dispersion characteristics almost midway between PSF (polysulfone) and PC (polycarbonate) are used, then tolerable results have arisen. That is, the products Δn at center wavelengths of approximately 550, 450, and 630 nm are approximately 1.0, 1.08, and less than 0.98, respectively.

Where the liquid crystal displays according to Embodiments 1-4 are operated so as to achieve reduction in shadow effects, the optimum correction somewhat sacrifices the contrast. Therefore, in OFF state (black state), it is essential to achieve complete light shielding. Also, it is imperative that commercial products adopt colored beads.

In one kind of colored beads, each transparent particle is coated with a colored layer. Japanese Patent Unexamined Publication No. 9027/1993 discloses another kind of colored beads which are made of black, inorganic spacer particles. Japanese Patent Unexamined Publication No. 2913/1995 discloses another kind of colored beads consisting of fine particles of a polymer in which a dye is uniformly dispersed. To achieve complete light shielding when a black picture is displayed, it is desired to use beads that are totally colored and thus produce excellent light-shielding effects because, where a thin colored layer is formed on the surface of each spherical bead, portions closer to the center of the bead transmits light to a higher degree.

To prevent the orientation at the surfaces of the colored beads from deteriorating, it is desired to form a coating made either of an isocyanate-based coupling agent as described in Japanese Patent Unexamined Publication No. 33723/1991 or of an organic silane compound as described in Japanese Patent Unexamined Publication No. 110523/1996. To prevent the orientation from being deteriorated due to mechanical impact, long-chain alkyl group is preferably deposited on the surfaces of colored beads, the alkyl group being bonded to chains of graft copolymer, as described in Japanese Patent Unexamined Publication No. 328018/1996.

Accordingly, beads for use with the liquid crystal display in accordance with the present invention are preferably colored up to their centers and coated with films of plural organic or inorganic materials or combination thereof to prevent the orientation at the surfaces of the beads from deteriorating.

The above mentioned embodiments can provide a liquid crystal display which is driven at a high frame frequency of about 150 Hz or more, shows good image quality (i.e., has small picture nonuniformities), and exhibits high-speed response, high contrast, and wide viewing angle.

The present invention can provide a liquid crystal display showing high quality image by subject matters on each embodiments or sevral combinations of each embodiments.

Claims

1. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

   a pair of opposite electrode substrates (30, 31) having scanning and data electrodes that intersect each other such that dots are formed at intersections of these scanning and data electrodes;

   a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a given subinterval;

   a data electrode driver circuit (103) for applying a signal voltage to said data electrode according to data about a picture to be displayed; and

   a power circuit (114) for supplying the non-select voltage and the select voltage to said scanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit comprising a resistor (R5) used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier (136, 151) circuit for amplifying the detected electrical current, and a correcting voltage-generating circuit (152) for applying the non-select voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on a reference voltage to said scanning electrode driver circuit, said correcting voltage-generating circuit having a function of resetting the output from said operational amplifier circuit every subinterval.

2. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

   a pair of opposite electrode substrates (30, 31) having scanning and data electrodes that intersect each other such that dots are formed at intersections of these scanning and data electrodes;

   a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a given time interval;

   a data electrode driver circuit (103) for applying a signal voltage to said data electrode according to data about a picture to be displayed; and

   a power circuit (114) for supplying the non-select voltage and the select voltage to said scanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit comprising a resistor (R5) used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier (136, 151) circuit for amplifying the detected electrical current, and a correcting voltage-generating circuit (152) for applying the non-select voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on a reference voltage to said scanning electrode driver circuit, said correcting voltage-generating circuit having a function of resetting the output from said operational amplifier circuit at every predetermined number time interval.

3. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

   a pair of opposite electrode substrates (30, 31) having scanning and data electrodes that intersect each other such that dots are formed at intersections of these scanning and data electrodes;

   a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a given time interval;

   a data electrode driver circuit (103) for applying a signal voltage to said data electrodes according to data about a picture to be displayed;

   a power circuit (114) for supplying two different positive select voltages being above a given reference voltage and two different negative select voltages being below said given reference voltage to said scanning electrode driver circuit, said two positive select voltages being different from each other and said two negative select voltages being different from each other, said power circuit further supplying a voltage generated by superimposing a correcting voltage on said given reference voltage as said non-select voltage to said scanning electrode driver circuit and supplying three kinds of voltages to said data electrode driver circuit; and

a correcting clock-generating circuit (109, 148) for generating a pulse signal according to contents of a picture to be displayed;
said power circuit comprising a resistor (R5) used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier circuit (136, 151) for amplifying the detected electrical current, and a correcting voltage-generating circuit (152) for applying the nonselect voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on said reference voltage to the scanning electrodes driver circuit, said correcting voltage-generating circuit having a function of resetting the output from said operational amplifier circuit at every predetermined number time interval; and
said scanning electrode driver circuit supplying one of said four select voltages as a select voltage to at least one of said scanning electrodes according to said pulse signal.

4. A liquid crystal display according to claim 2 or 3, wherein said correcting voltage-generating circuit has a function of resetting said output from said operational amplifier circuit at every one time interval.

5. A liquid crystal display according to claims 1 - 3, wherein said power circuit further comprises a signal modulation circuit (146) having a pair of bidirectional diodes being inserted between said operational amplifier circuit and said correcting voltage-generating circuit.

6. A liquid crystal display according to claims 1 - 3, wherein said power circuit further comprises a limiter circuit (147) having a pair of bidirectional diodes being inserted between said reference voltage and an output of said operational amplifier circuit.

7. A liquid crystal display of any one of claims 1 - 3, wherein said scanning electrode driver circuit applies the select voltage according to given orthogonal functions to plural ones of said scanning electrodes sequentially, and wherein said signal electrode driver circuit applies a signal voltage according to said orthogonal functions and the contents of the picture to be displayed.

8. A liquid crystal display of any one of claims 1 - 3, wherein said operational amplifier circuit includes an operational amplifier having an inverting terminal and a non-inverting terminal to which both terminals of said resistor used to detect the electrical current are respectively connected indirectly, and wherein said operational amplifier exhibits an inverting amplification ratio and a non-inverting amplification ratio that are different from each other.

9. A liquid crystal display according to claims 1 - 3, wherein said electrode substrates are separated by a gap of d that is 4 to 7 μm, and wherein a liquid crystal material exhibiting a viscosity of less than 20 mPa • s at 20 °C is interposed between said electrode substrates.

10. A liquid crystal display according to claims 1 - 3, wherein said electrode substrates are separated by a gap of d that is 5 to 6 μm, and wherein a liquid crystal material exhibiting a viscosity of less than 15 mPa • s at 20 °C is interposed between said electrode substrates.

11. A liquid crystal display according to claims 1 - 3, wherein said electrode substrates are separated by a gap of d that is approximately 6 μm, and wherein a liquid crystal material exhibiting a viscosity of less than 13 mPa • s at 20 °C is interposed between said electrode substrates.

12. The liquid crystal display according to claims 1 - 3, wherein said liquid crystal display is operated at a frame frequency of more than 150 Hz, and wherein a difluorostilbene-based liquid crystal material is used between said electrode substrates.

13. A liquid crystal display according to claims 1 - 3, further comprising:

a backlighting system outputting three-wavelength light source emitting three strong wavelengths of approximately 450, 550, and 630 nm;

a pair of polarizing sheets (32, 33) mounted on opposite sides of said electrode substrates; and at least one phase-difference film (34, 35) having a refractive index anisotropy Δn possessing such wavelength dispersion characteristics that Δn at wavelengths of approximately 550, 450, and 630 nm are approximately 1.0, 1.1, and 0.97, respectively.

14. The light crystal display according to claims 1 - 3, further comprising:

a backlighting system outputting three-wavelength light source emitting three strong wavelengths of approximately 450, 550, and 630 nm;

a pair of polarizing sheets (32, 33) mounted on opposite sides of said electrode substrates; and

at least one phase-difference film (34, 35) made of polysulfone.

15. A liquid crystal display according to claims 1, 2 or 3, wherein said liquid crystal display is operated at a frame frequency of more than 150 Hz, and wherein spacers including colored beads are used between said electrode substrates, said colored beads being colored up to their centers, and colored beads being coated with films of plural kinds of organic or inorganic substances or combination thereof.

16. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

scanning and data electrodes that intersect each other;

a pair of substrates (30, 31) opposing each other via liquid crystal layer;

a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a predetermined time interval;

a data electrode driver circuit (103) for applying a signal voltage to said data electrode according to data about a picture to be displayed;

a correcting clock signal generating circuit (109, 148) generating a pulse signal according to contents of a picture to be displayed; and

a power circuit (114) for supplying the non-select voltage and the select voltage to said scanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit supplying a voltage superimposed a compensating voltage according to an electrical current in a scanning electrode while non-selected period on a first reference voltage as the non-select voltage,
said scanning electrode driver circuit supplying a voltage superimposed a compensating voltage according to said pulse signal on a second reference voltage as said select voltage.

17. A liquid crystal display according to claim 16, wherein said power circuit has a function of resetting said compensating voltage according to an electrical current in a scanning electrode while non-selected period at every one time interval.

18. A liquid crystal display according to claim 16, wherein said power circuit restore said voltage superimposed a compensating voltage according to an electrical current in a scanning electrode while non-selected period into said first reference voltage.

19. A liquid crystal display according to claim 16, wherein said power circuit comprise a resistor (R5) used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier circuit for amplifying the detected electrical current, a correcting voltage-generating circuit for applying the voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on said first reference voltage and a signal modulation circuit having a pair of bidirectional diodes being inserted between said operational amplifier circuit and said correcting voltage-generating circuit.

20. A liquid crystal display according to claim 19, wherein said power circuit further comprises a limiter circuit (147) having a pair of bidirectional diodes being inserted between said first reference voltage and an output of said operational amplifier circuit.

21. A liquid crystal display according to claim 19, wherein said operational amplifier circuit includes an operational amplifier having an inverting terminal and a non-inverting terminal to which both terminals of said resistor used to detect the electrical current are respectively connected indirectly, and wherein said operational amplifier exhibits an inverting amplification ratio and a non-inverting amplification ratio that are different from each other.

22. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

scanning and data electrodes that intersect each other;

a pair of substrates (30, 31) opposing each other via liquid crystal layer;

a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a predetermined time interval;

a data electrode driver circuit (103) for applying a signal voltage to said data electrode according to data about a picture to be displayed; and

a power circuit (114) for supplying the non-select voltage and the select voltage to said scanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit supplying a voltage superimposed a compensating voltage according to an electrical current in a scanning electrode while non-selected period on a predetermined reference voltage as the non-select voltage, said power circuit resetting said compensating voltage at every one time interval.

23. A liquid crystal display having a voltage-compensating function, said liquid crystal display comprising:

scanning and data electrodes that intersect each other;

a pair of substrates (30, 31) opposing each other via liquid crystal layer;

a scanning electrode driver circuit (102) for applying a non-select voltage or a select voltage to said scanning electrodes during a predetermined time interval;

a data electrode driver circuit (103) for applying a signal voltage to said data electrode according to data about a picture to be displayed; and

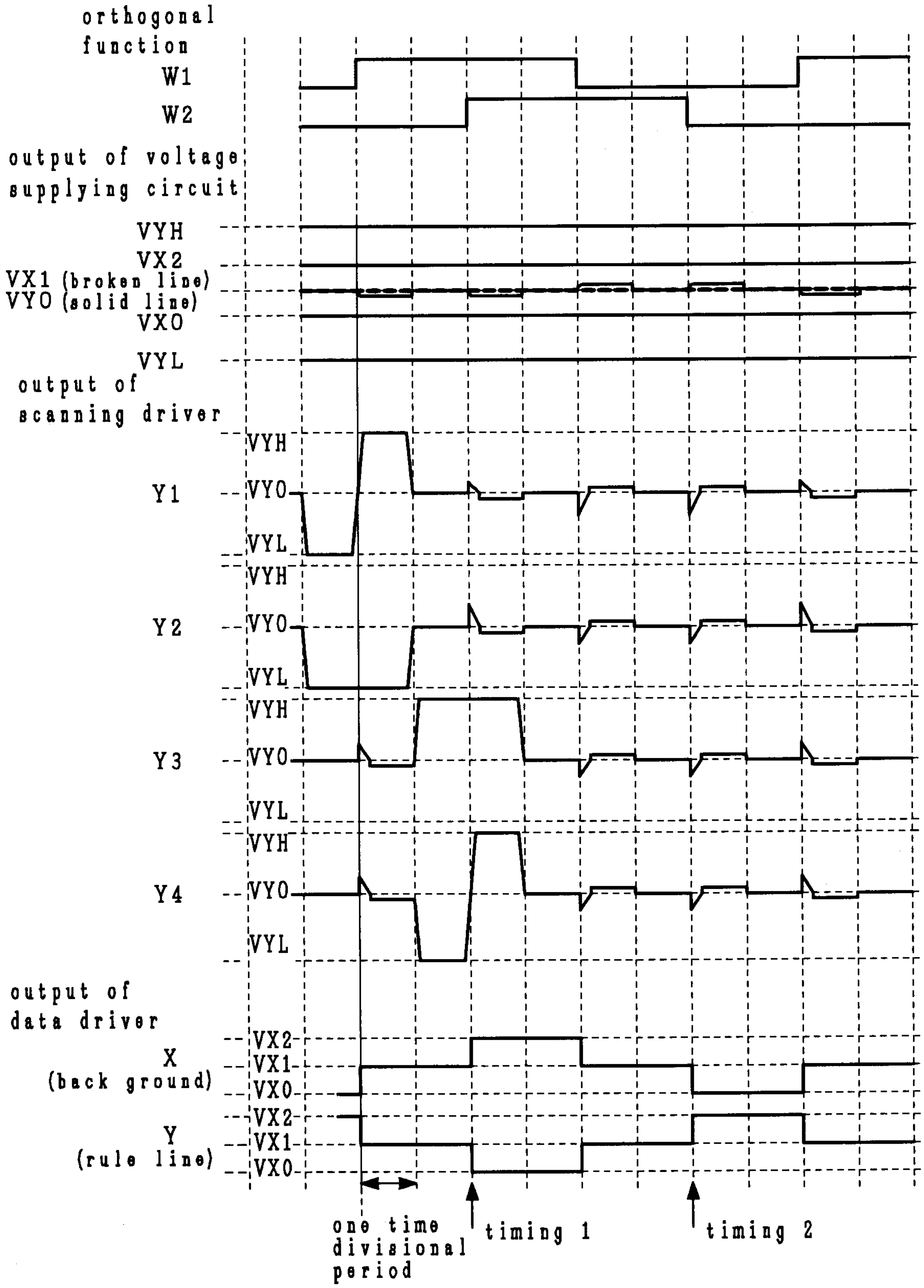
a power circuit (114) for supplying the non-select voltage and the select voltage to said scanning electrode driver circuit and a voltage to said data electrode driver circuit, said power circuit supplying a voltage superimposed a compensating voltage according to an electrical current in a scanning electrode while non-selected period on a predetermined reference voltage as the non-select voltage, said power circuit restoring said non-select voltage into said reference voltage at every one time interval.

24. A liquid crystal display according to claim 22 or 23, wherein said power circuit comprises a resistor (R5) used to detect an electrical current flowing through scanning electrodes to which said non-select voltage is applied, an operational amplifier circuit (136, 151) for amplifying the detected electrical current, a correcting voltage-generating circuit (152) for applying the voltage by superimposing a correcting voltage derived from said output of said operational amplifier circuit on said first reference voltage and a signal modulation circuit (146) having a pair of bidirectional diodes being inserted between said operational amplifier circuit and said correcting voltage-generating circuit.

25. A liquid crystal display according to claim 24, wherein said power circuit further comprises a limiter circuit (147) having a pair of bidirectional diodes being inserted between said first reference voltage and an output of said operational amplifier circuit.

26. A liquid crystal display according to claim 24, wherein said operational amplifier circuit includes an operational amplifier having an inverting terminal and a non-inverting terminal to which both terminals of said resistor used to detect the electrical current are respectively connected indirectly, and wherein said operational amplifier exhibits an inverting amplification ratio and a non-inverting amplification ratio that are different from each other.

FIG. 1



orthogonal function
W1
W2
output of voltage supplying circuit
VYH
VX2
VX1 (broken line)
VY0 (solid line)
VX0
VYL
output of scanning driver
Y1
Y2
Y3
Y4
VYH
VY0
VYL
output of data driver
X (back ground)
Y (rule line)
VX2
VX1
VX0
one time divisional period
timing 1
timing 2

FIG. 2

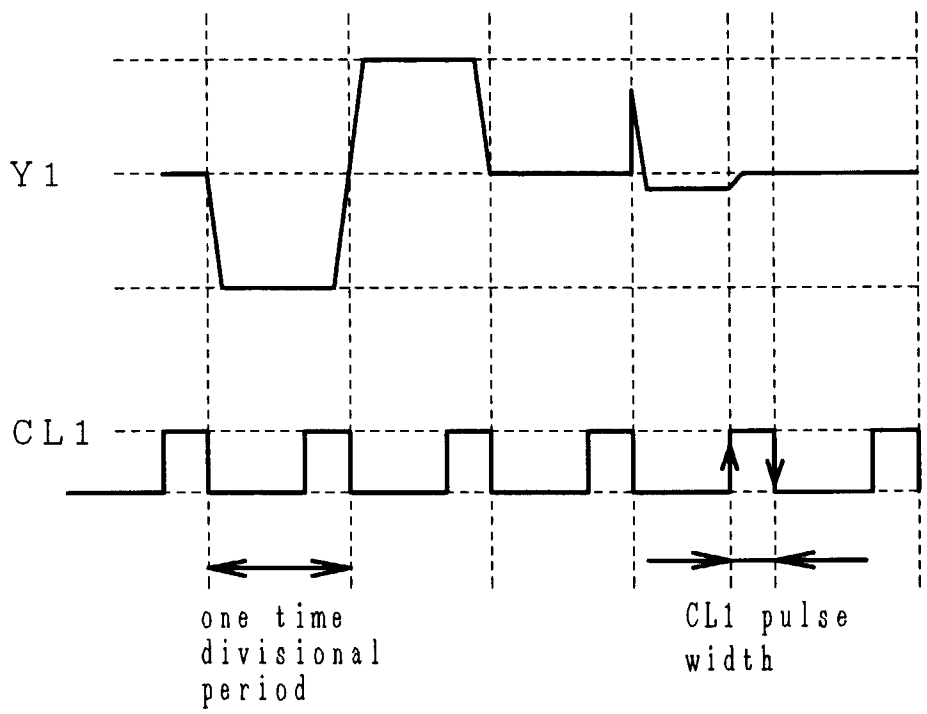


FIG. 3

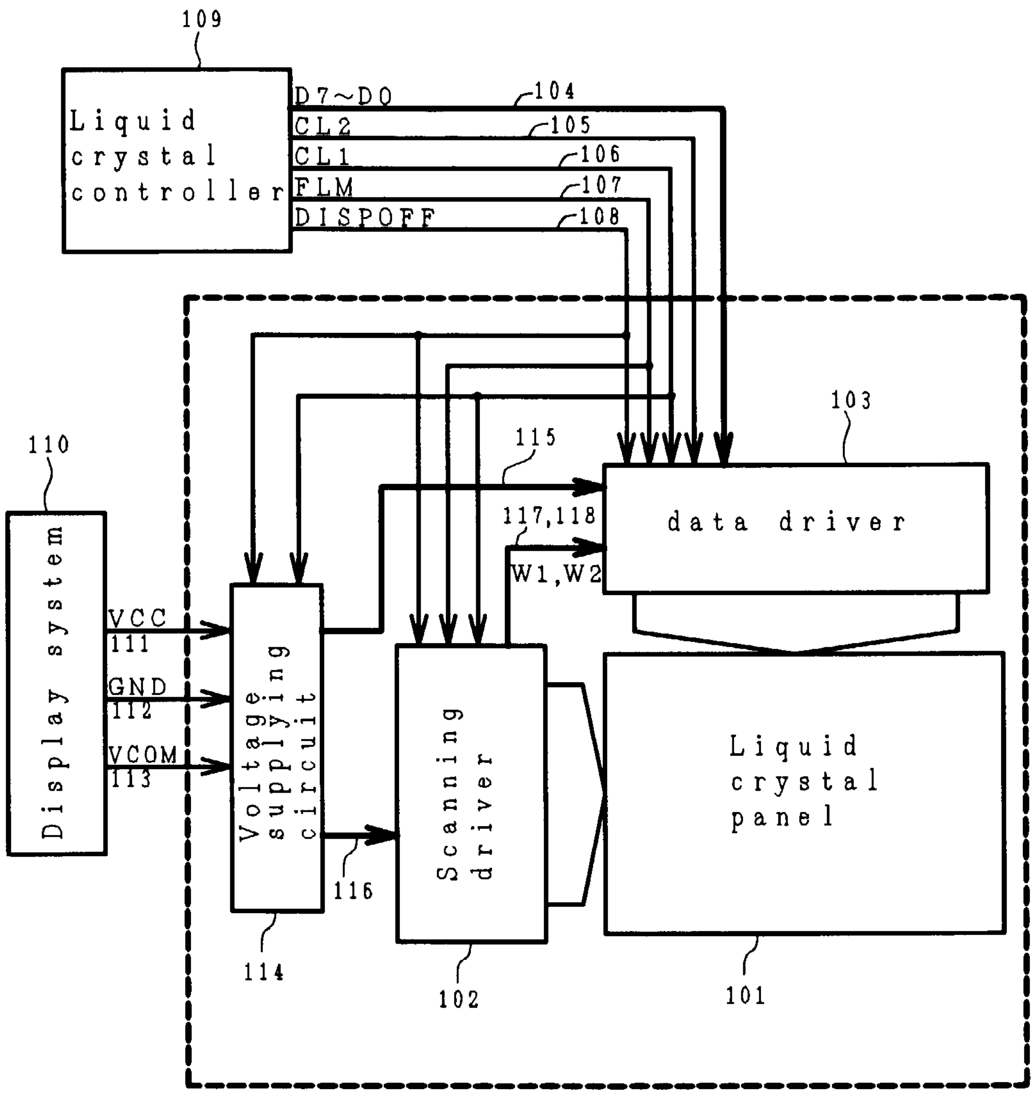

109
Liquid crystal controller
D7~D0
104
CL2
105
CL1
106
FLM
107
DISPOFF
108
110
Display system
VCC
111
GND
112
VCOM
113
Voltage supplying circuit
114
115
116
117,118
W1,W2
Scanning driver
102
data driver
103
Liquid crystal panel
101

FIG. 4

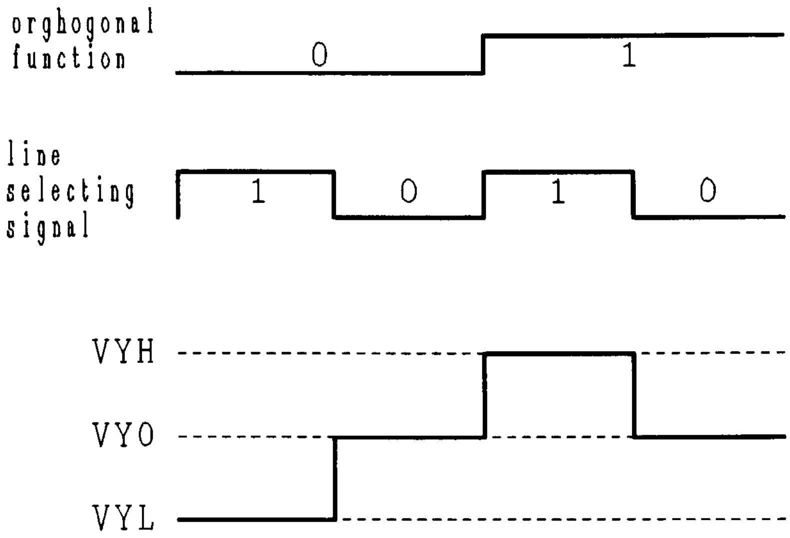

orghogonal function
0
1
line selecting signal
1
0
1
0
VYH
VY0
VYL

FIG. 5

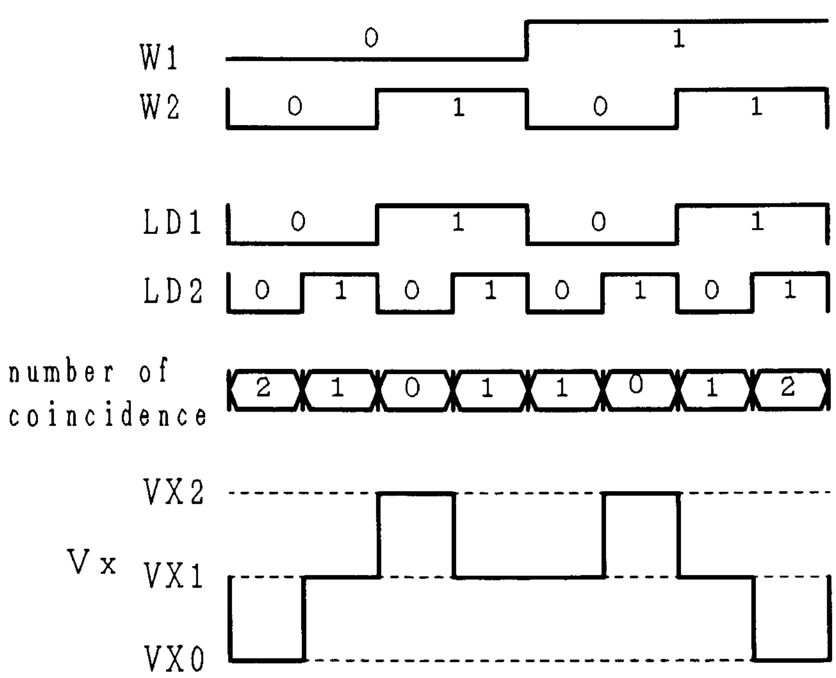

W1
0
1
W2
0
1
0
1
LD1
0
1
0
1
LD2
0 1 0 1 0 1 0 1
number of coincidence
2 1 0 1 1 0 1 2
Vx
VX2
VX1
VX0

FIG. 6

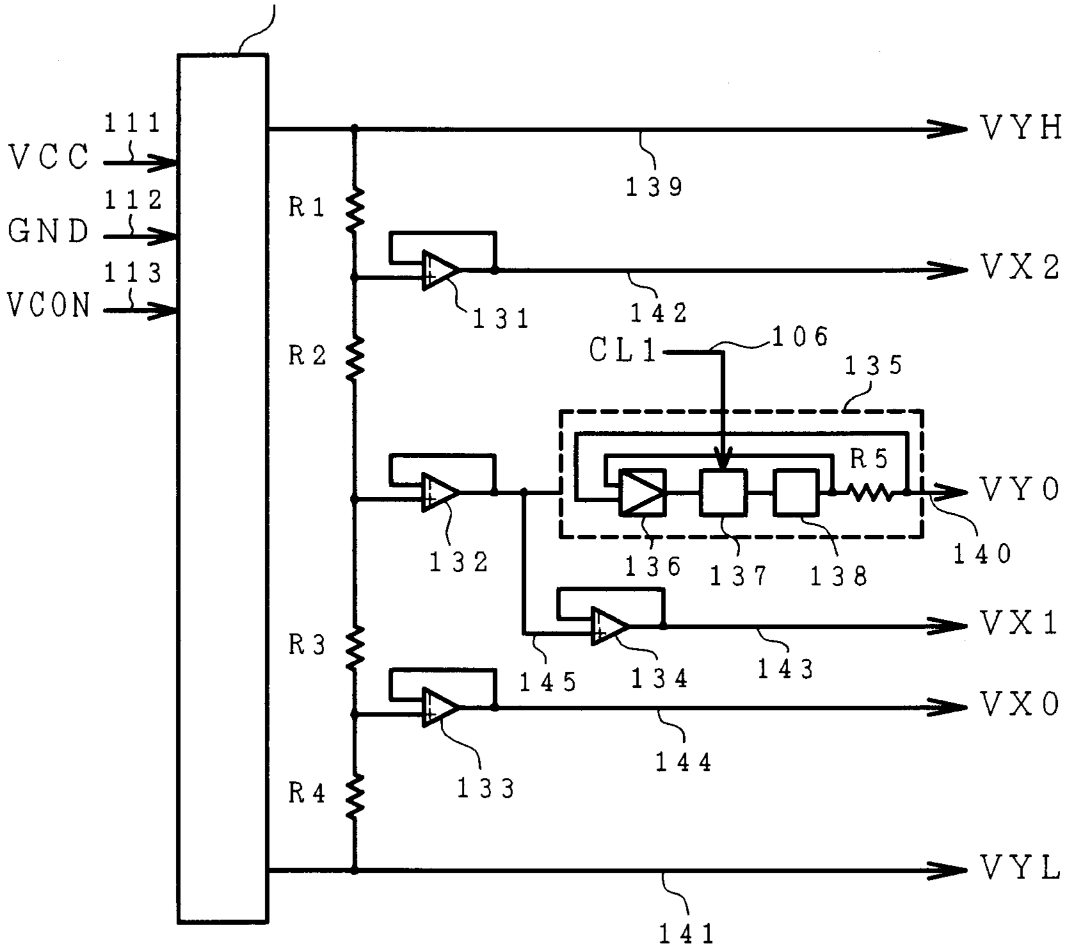

130
111
VCC
112
GND
113
VCON
R1
R2
R3
R4
VYH
139
VX2
131
142
CL1
106
135
R5
VY0
132
136
137
138
140
VX1
145
134
143
VX0
133
144
VYL
141

FIG. 7

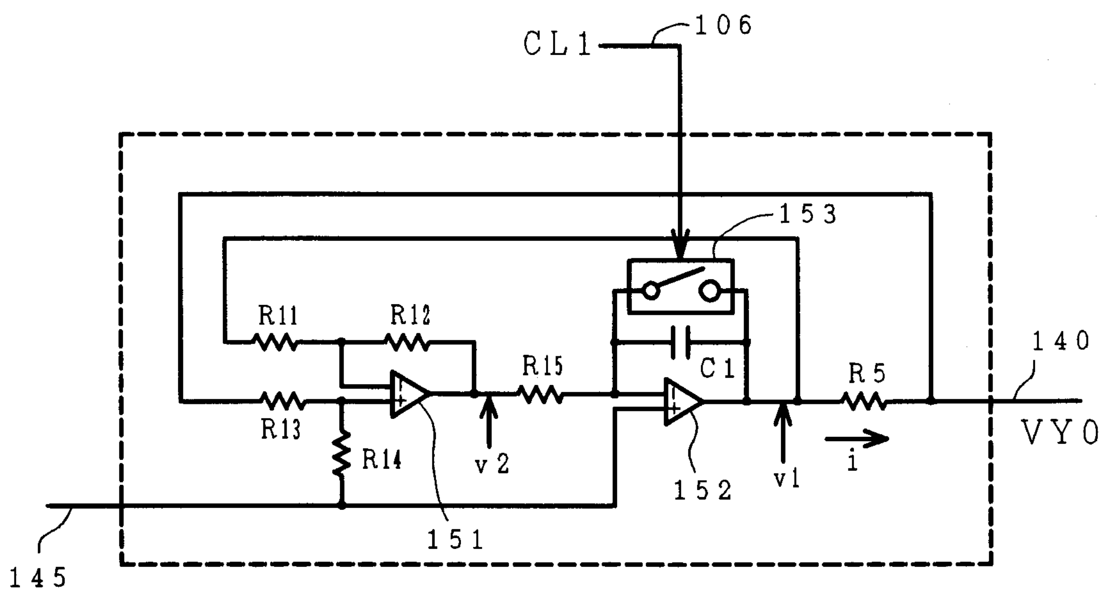

CL1
106
153
R11
R12
R15
C1
140
R5
R13
R14
v2
152
v1
i
VY0
151
145

FIG. 8

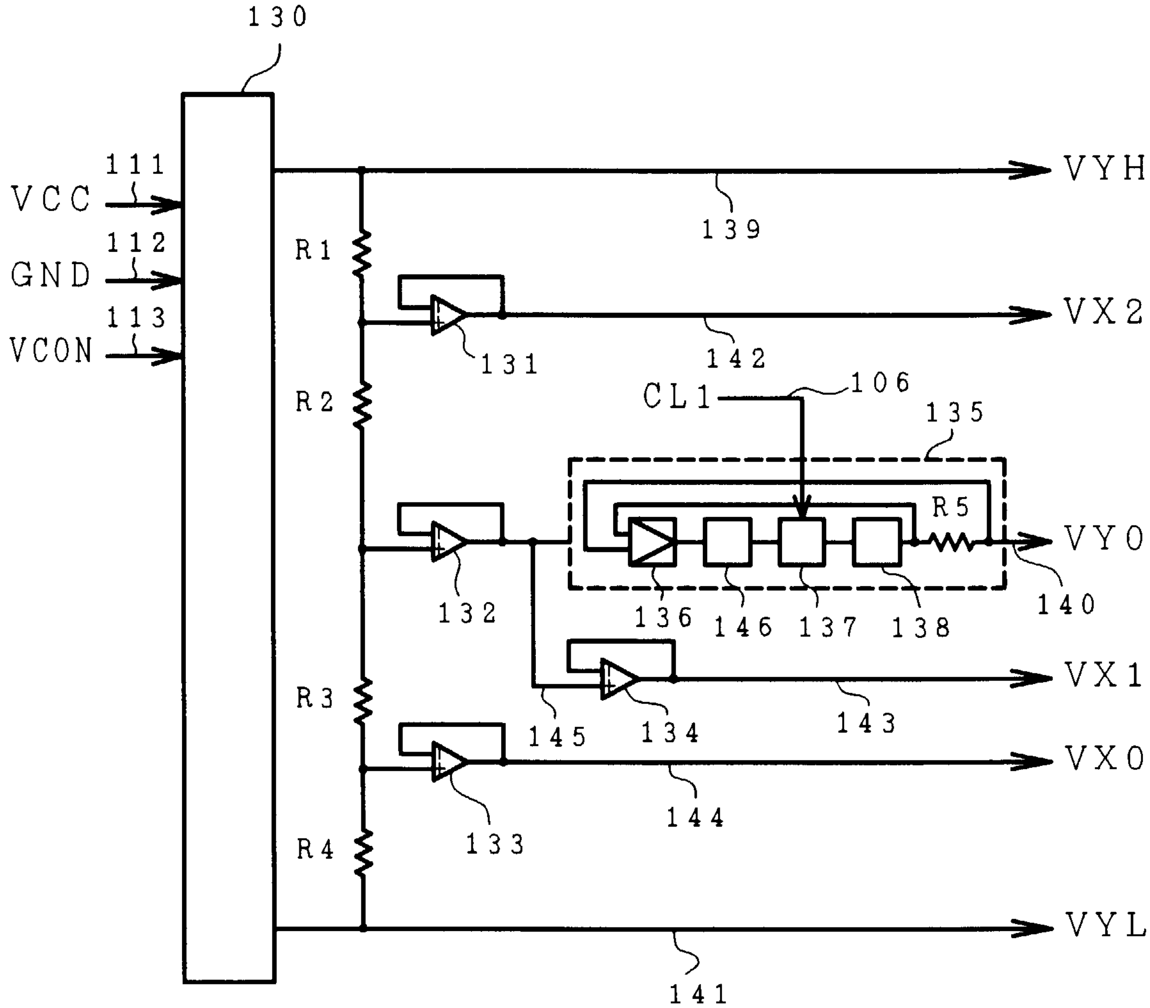

130
111
VCC
112
GND
113
VCON
R1
R2
R3
R4
VYH
139
VX2
142
131
CL1
106
135
R5
VY0
140
132
136
146
137
138
VX1
143
145
134
VX0
144
133
VYL
141

FIG. 9A

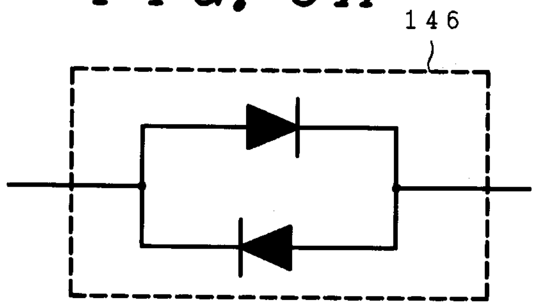


FIG. 9B

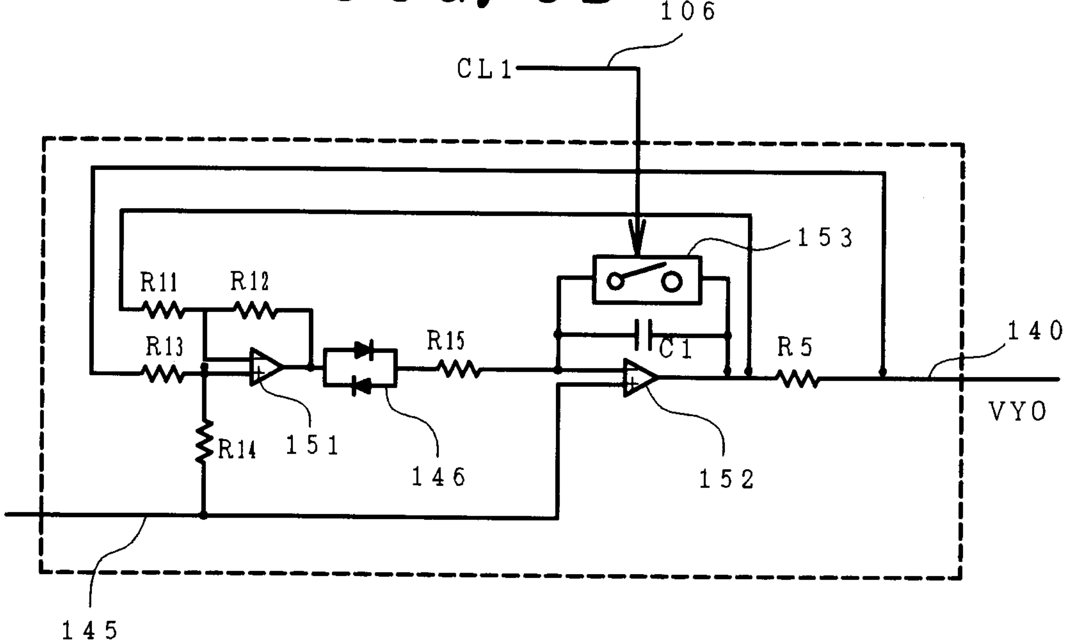


FIG. 10

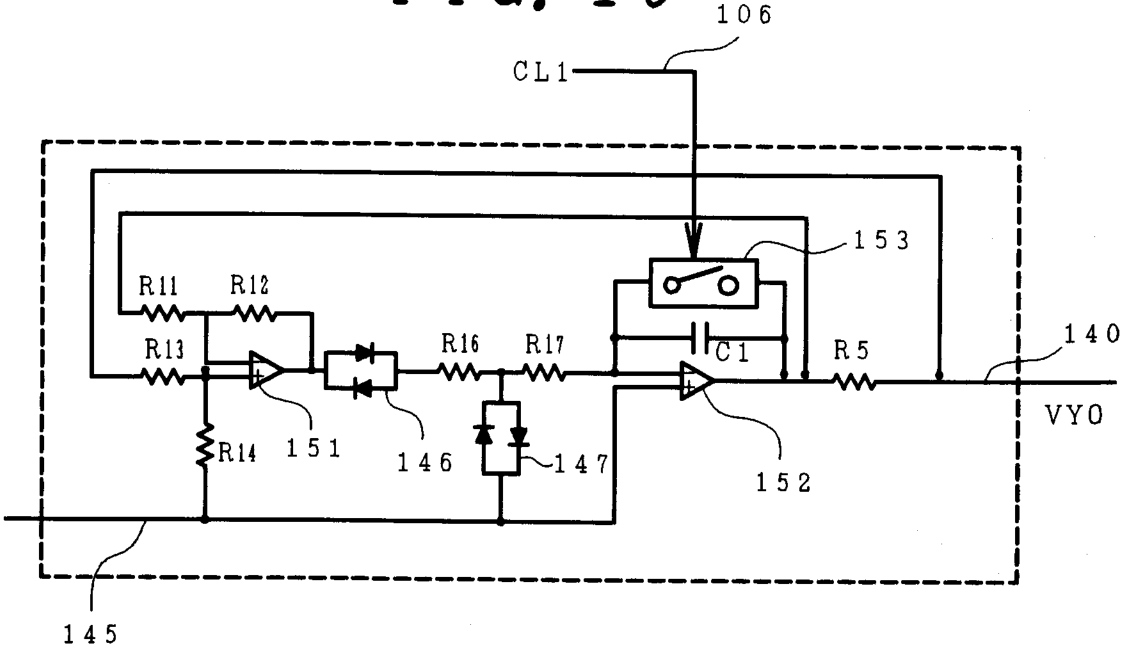


FIG. 11

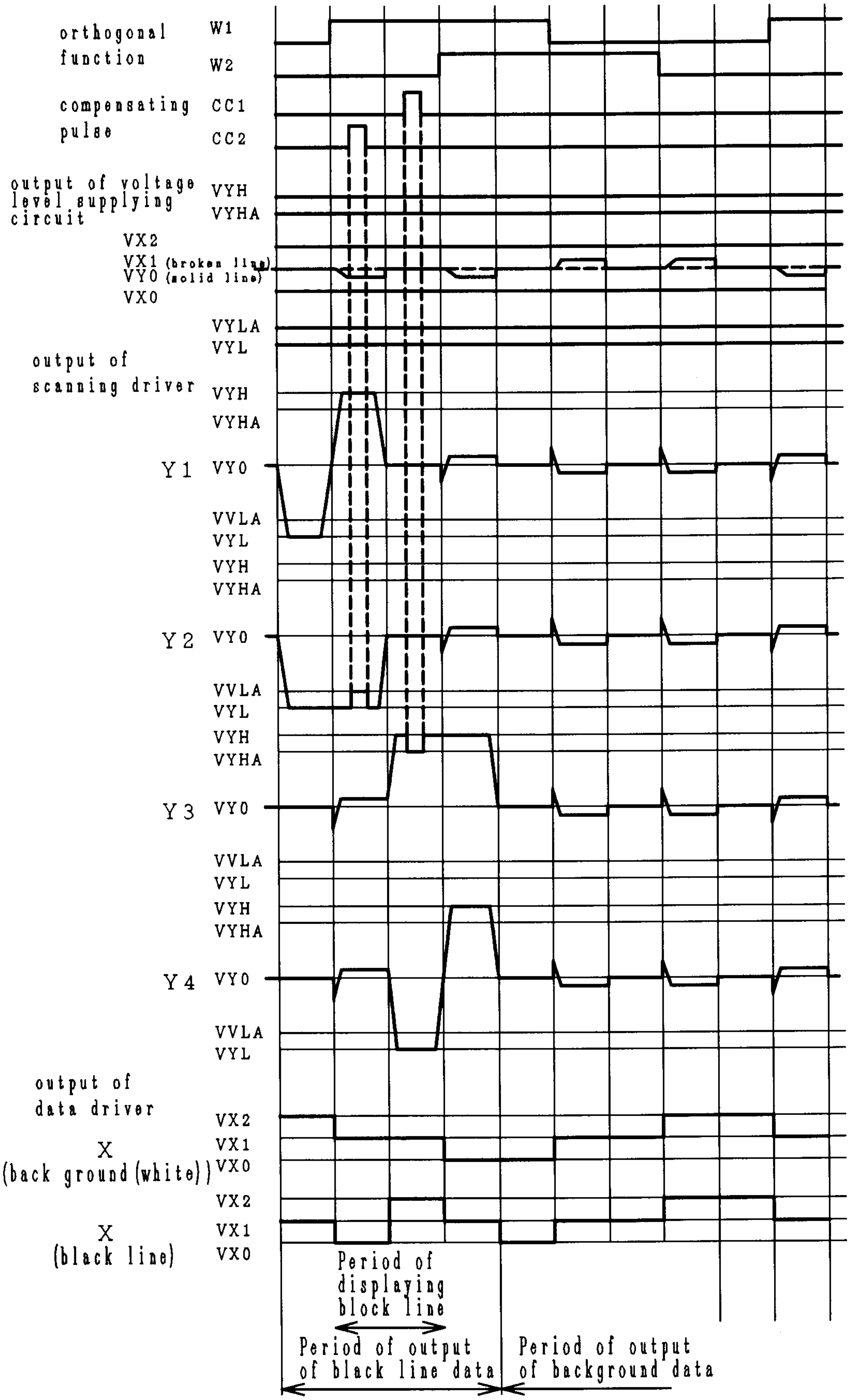

orthogonal function
W1
W2
compensating pulse
CC1
CC2
output of voltage level supplying circuit
VYH
VYHA
VX2
VX1 (broken line)
VY0 (solid line)
VX0
VYLA
VYL
output of scanning driver
Y1
Y2
Y3
Y4
VYH
VYHA
VY0
VVLA
VYL
output of data driver
X (back ground (white))
X (black line)
VX2
VX1
VX0
Period of displaying block line
Period of output of black line data
Period of output of background data

FIG. 12

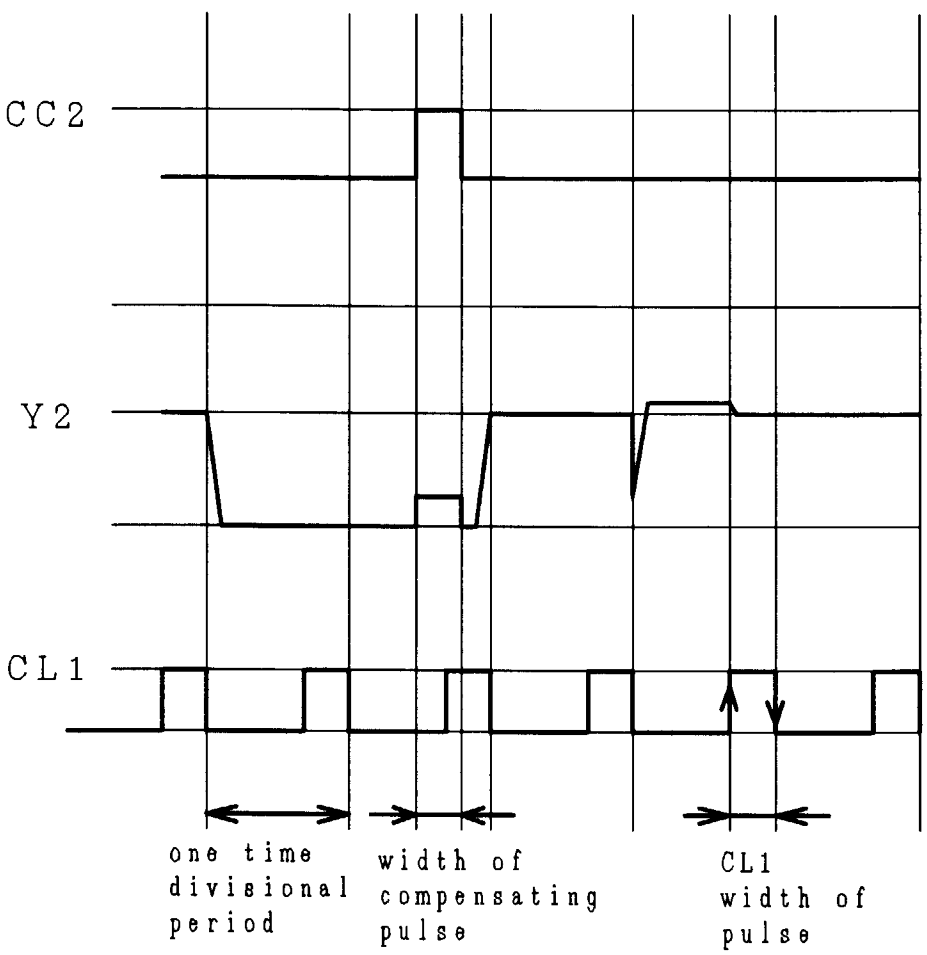

CC2
Y2
CL1
one time divisional period
width of compensating pulse
CL1 width of pulse

FIG. 13

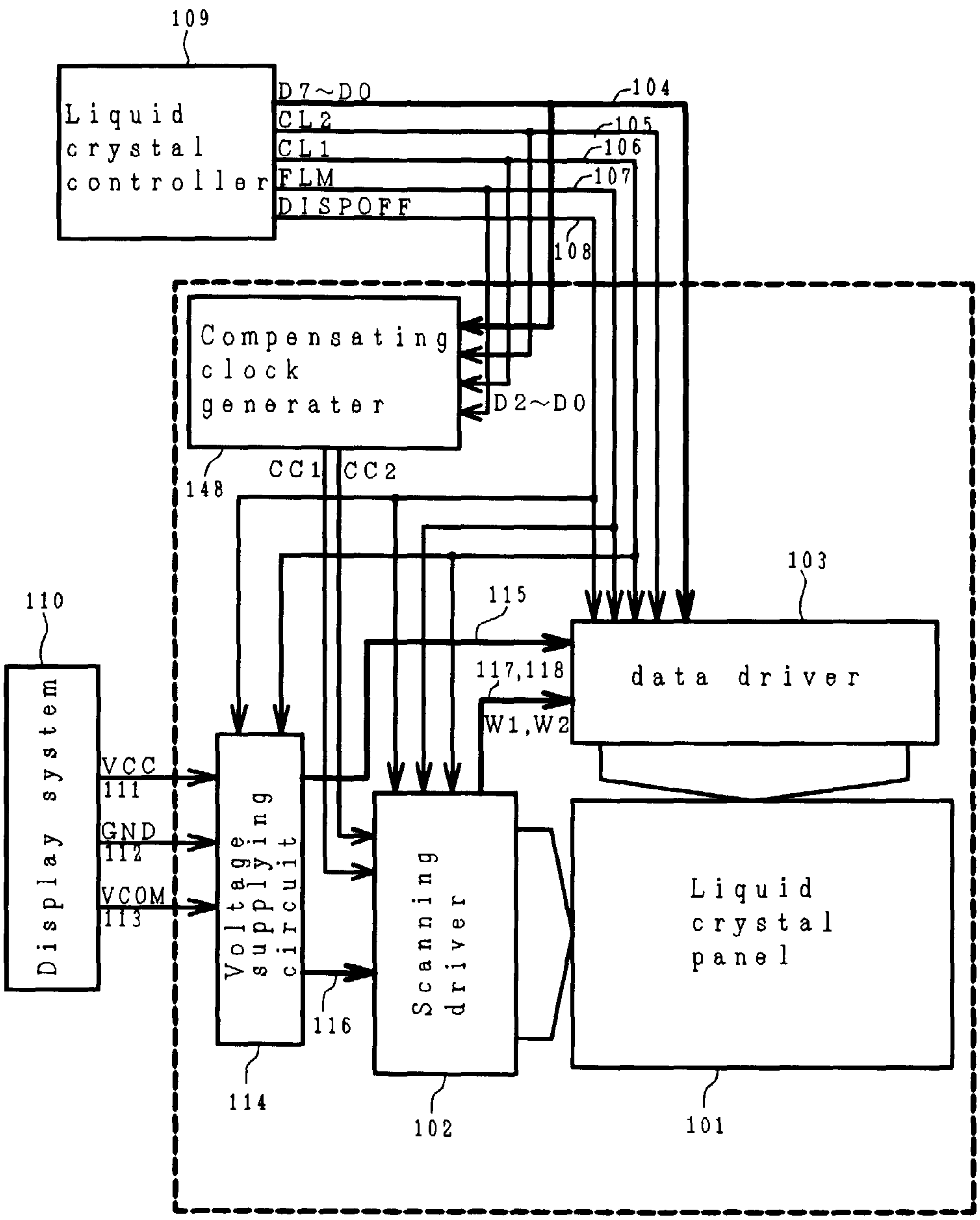

109
Liquid crystal controller
D7~D0
CL2
CL1
FLM
DISPOFF
104
105
106
107
108
Compensating clock generater
D2~D0
148
CC1
CC2
103
data driver
115
117,118
W1,W2
110
Display system
VCC
111
GND
112
VCOM
113
Voltage supplying circuit
116
114
Scanning driver
102
Liquid crystal panel
101

FIG. 14

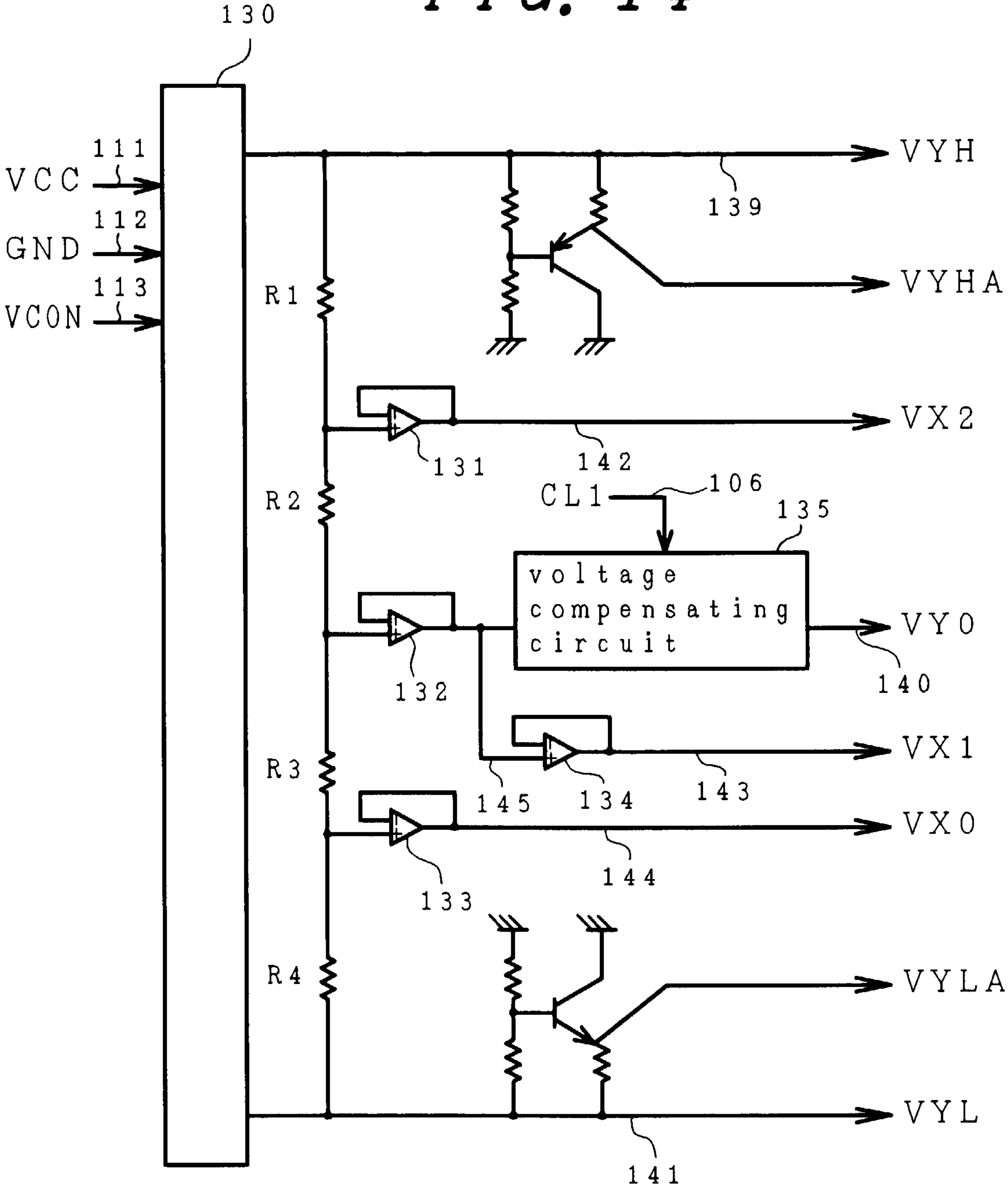

130
111
VCC
112
GND
113
VCON
VYH
139
VYHA
R1
VX2
131
142
R2
CL1
106
135
voltage
compensating
circuit
VY0
132
140
VX1
R3
145
134
143
VX0
144
133
R4
VYLA
VYL
141

FIG. 15

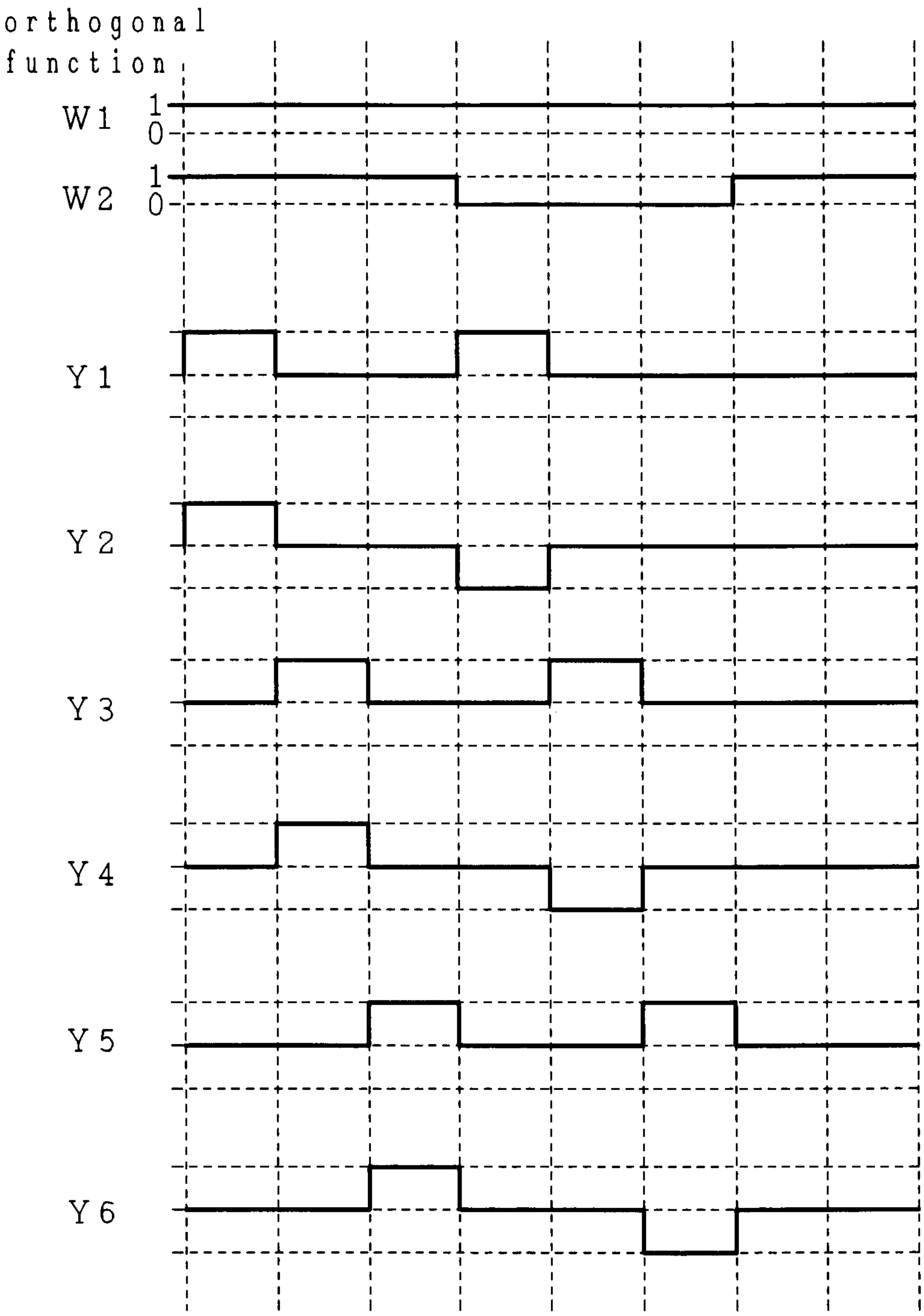


FIG. 16A

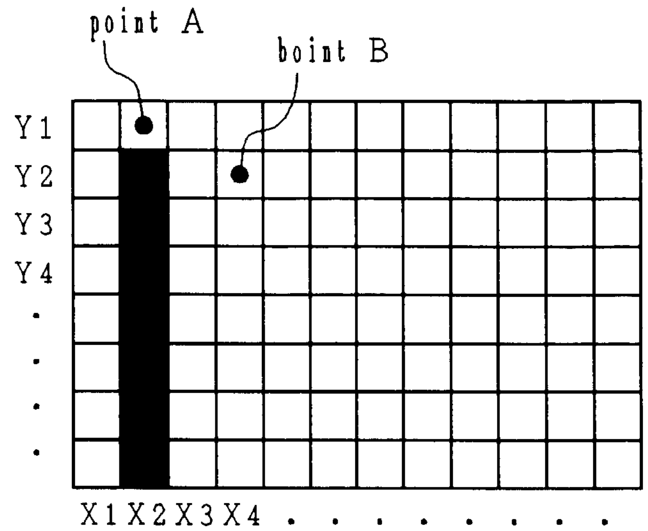


FIG. 16B

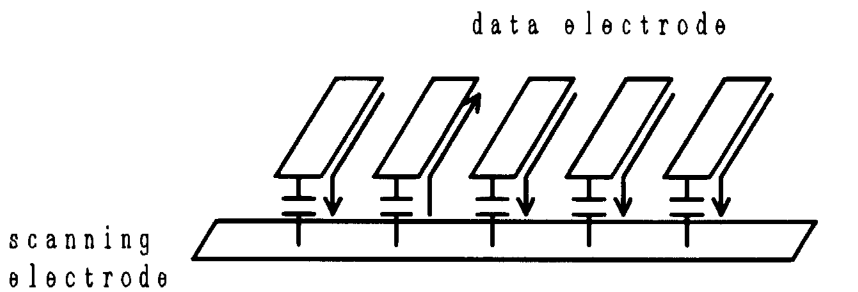


FIG. 16C

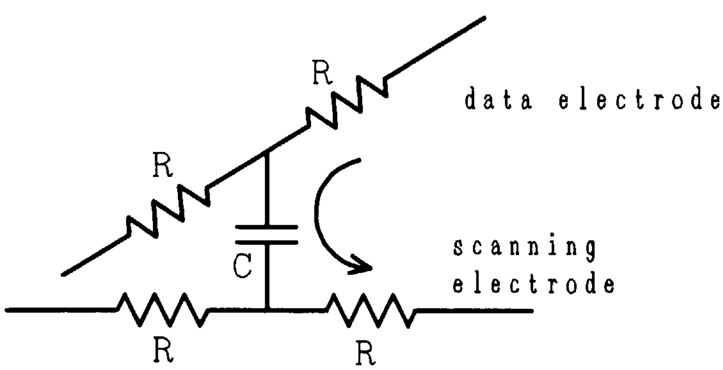


FIG. 17A

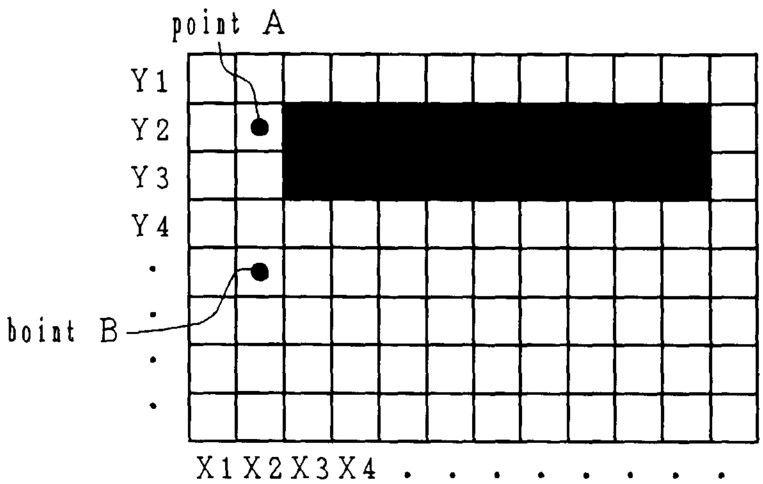


FIG. 17B

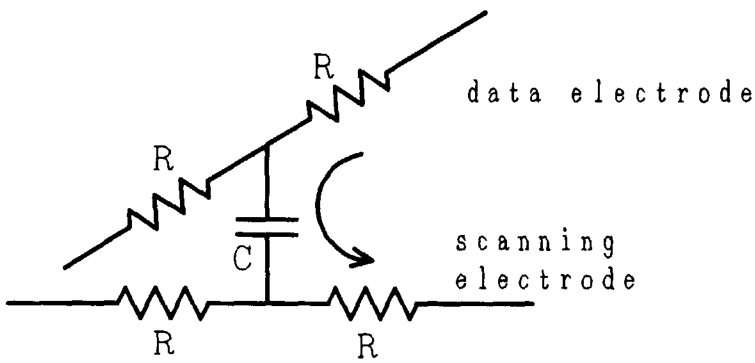


FIG. 17C

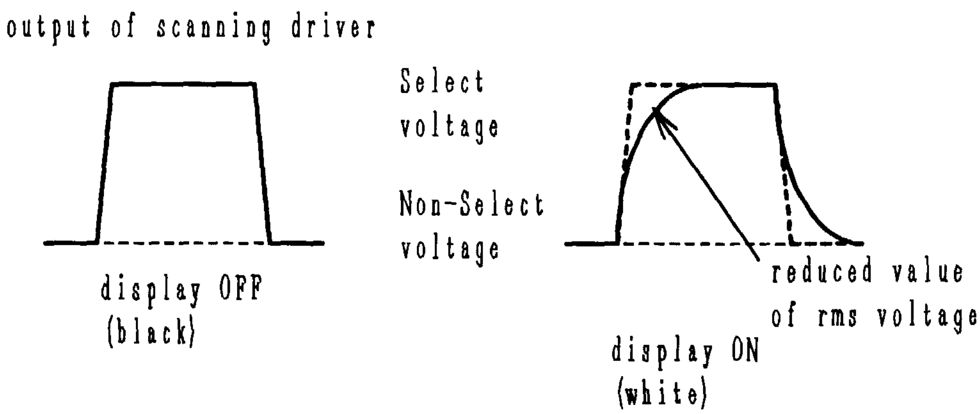


FIG. 18

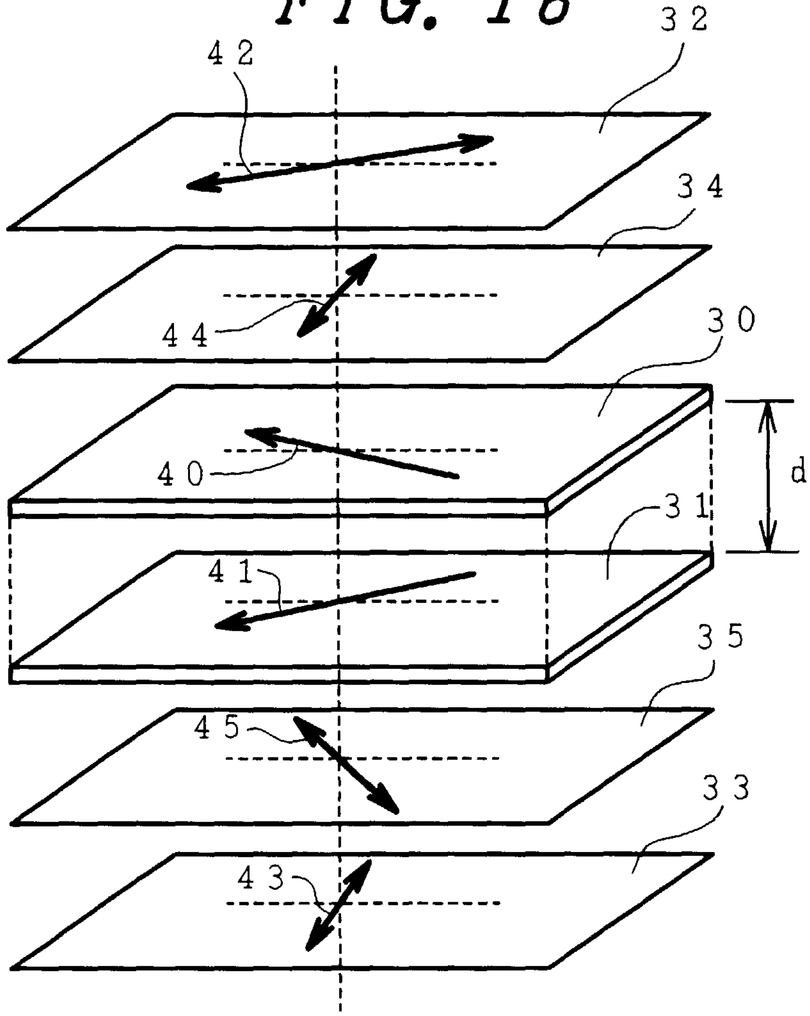


FIG. 19

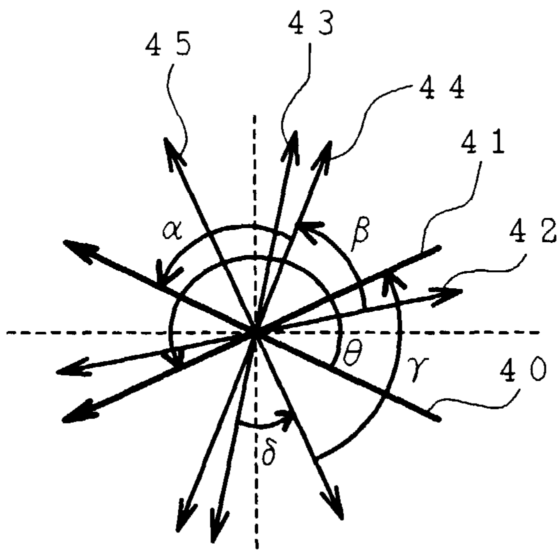
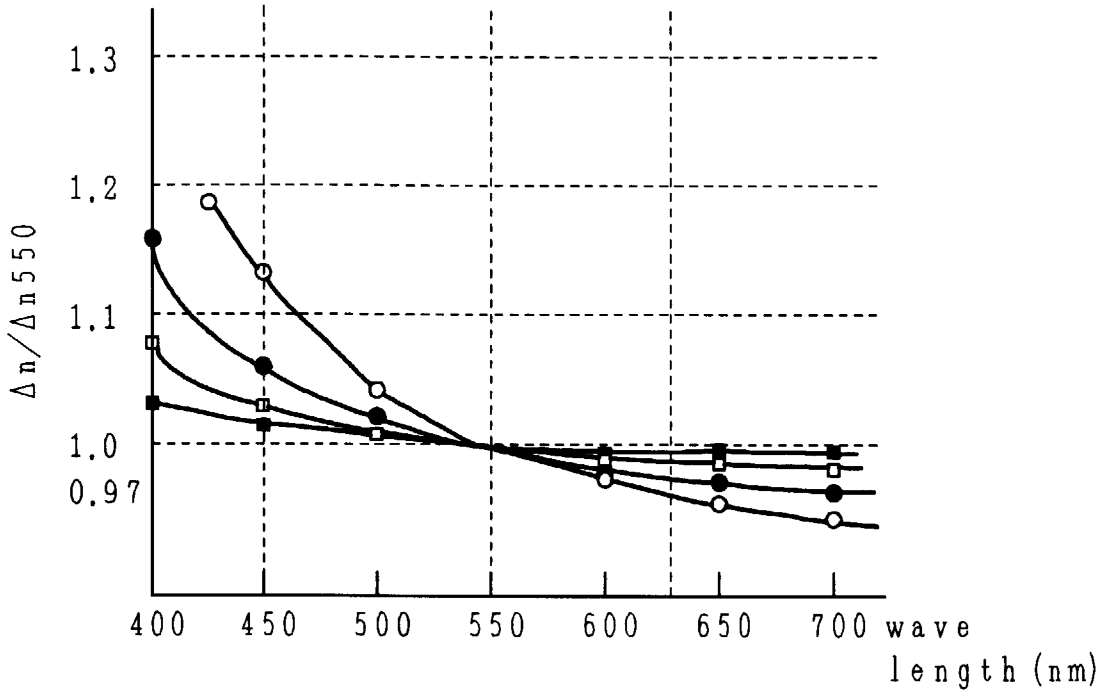


FIG. 20


1.3
1.2
1.1
1.0
0.97
Δn/Δn550
400
450
500
550
600
650
700
wave length (nm)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 12 2424

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 95 13603 A (IN FOCUS SYSTEMS INC)	1,7,22, 23	G09G3/36
Y	* page 10, line 33 - page 12, line 29 *	3,4,8, 16-18	
	* page 13, line 15 - page 15, line 20 * * page 16, line 34 - page 17, line 22 * * page 18, line 17 - page 19, line 14 * * page 20, line 11 - page 22, line 21 * * page 23, line 34 - page 24, line 8 * * figures 3,5A,8 *		
D,Y	US 5 442 370 A (YATABE SATOSHI ET AL)	3,4,8, 16-18	
	* column 17, line 49 - line 63 * * column 20, line 3 - line 20 * * column 64, line 31 - column 65, line 45 * * column 66, line 27 - line 65 * * column 67, line 55 - column 68, line 3 *		
A	* figures 99,103 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	EP 0 542 307 A (ASAHI GLASS CO LTD) * page 6, line 6 - page 7, line 50; figures 1,2 *	1,22,23	G09G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 May 1998	Amian, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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L : document cited for other reasons

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