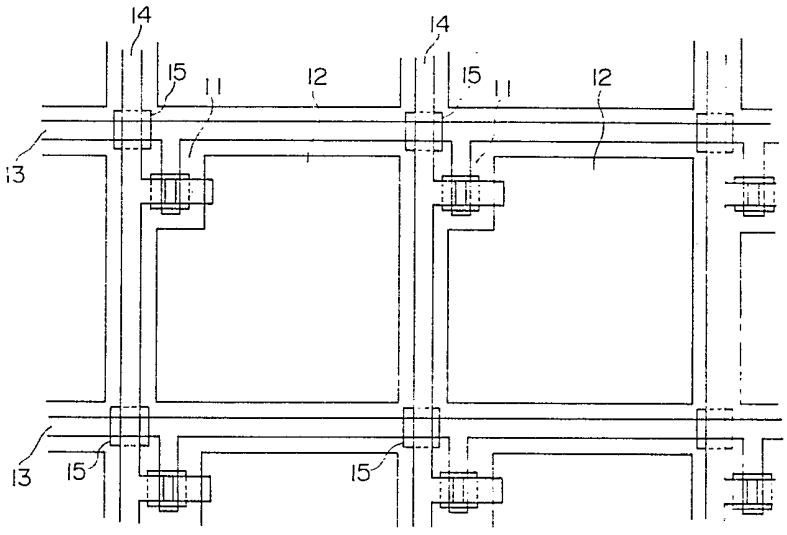
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(54) Liquid crystal display

(57) For driving a matrix type liquid crystal display device which includes a liquid crystal picture forming element (12) at the intersection of each line electrode (13) and column electrode (14) and in which each liquid crystal element is provided with a thin film transistor (11) connected to the row electrode and the column electrode, a scanning signal and a data signal are applied to the line electrode (13) and the column electrode (14) respectively, the scanning signal being advanced with respect to the data signal or the leading edge of the scanning signal being delayed with respect to the data signal. By using the above technique, the display contrast is made satisfactory even when the drive signal waveform is distorted by the resistances and capacitances of the line, column and display electrodes.

FIG. 1
(PRIOR ART)



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1
(PRIOR ART)

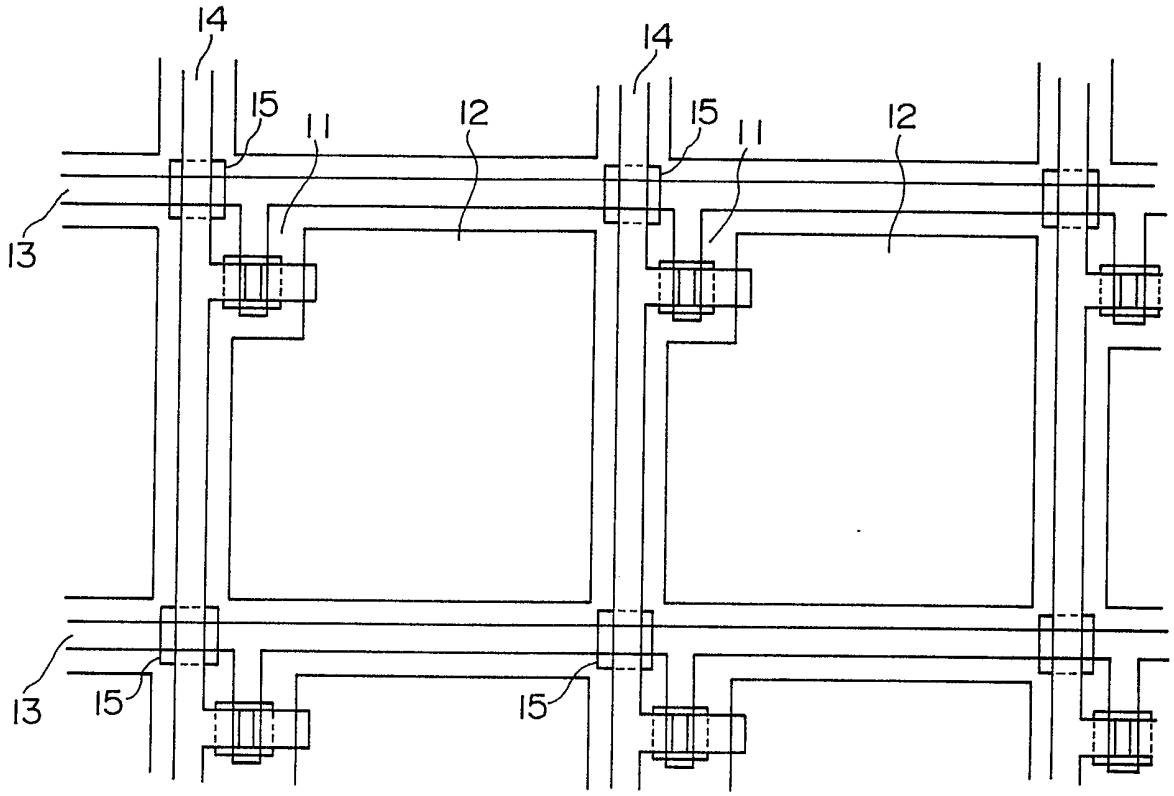
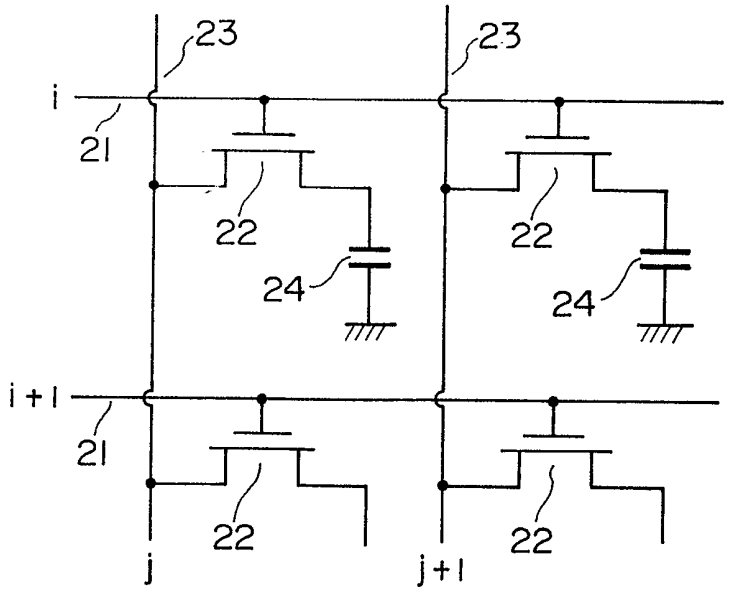


FIG. 2
(PRIOR ART)



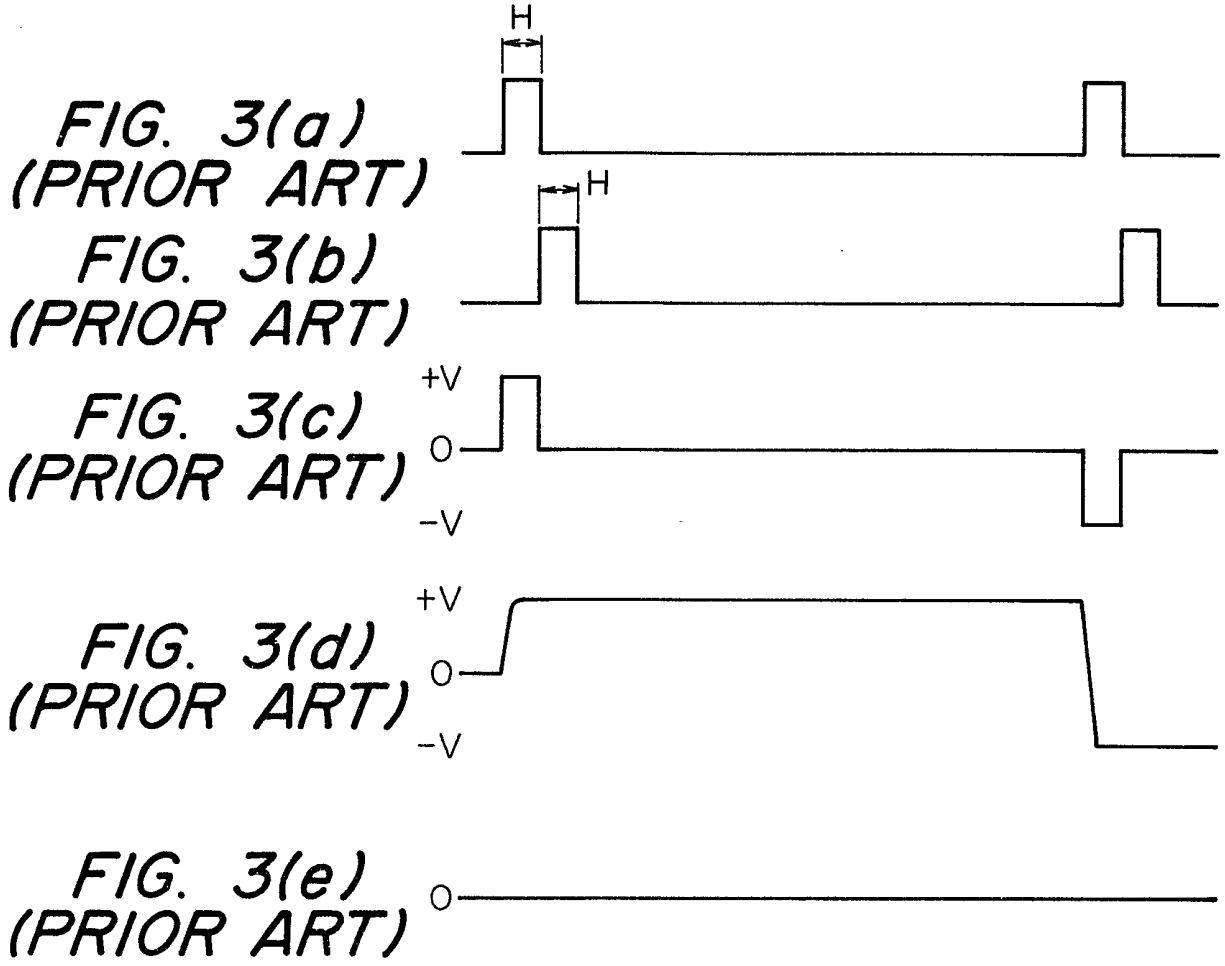


FIG. 3(a)
(PRIOR ART)

FIG. 3(b)
(PRIOR ART)

FIG. 3(c)
(PRIOR ART)

FIG. 3(d)
(PRIOR ART)

FIG. 3(e)
(PRIOR ART)

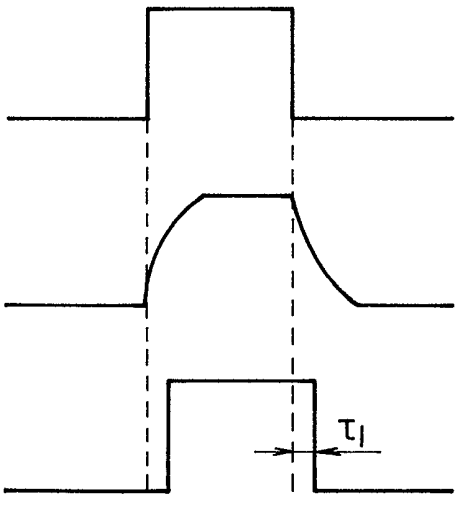


FIG. 4(a)
(PRIOR ART)

FIG. 4(b)
(PRIOR ART)

FIG. 4(c)
(PRIOR ART)

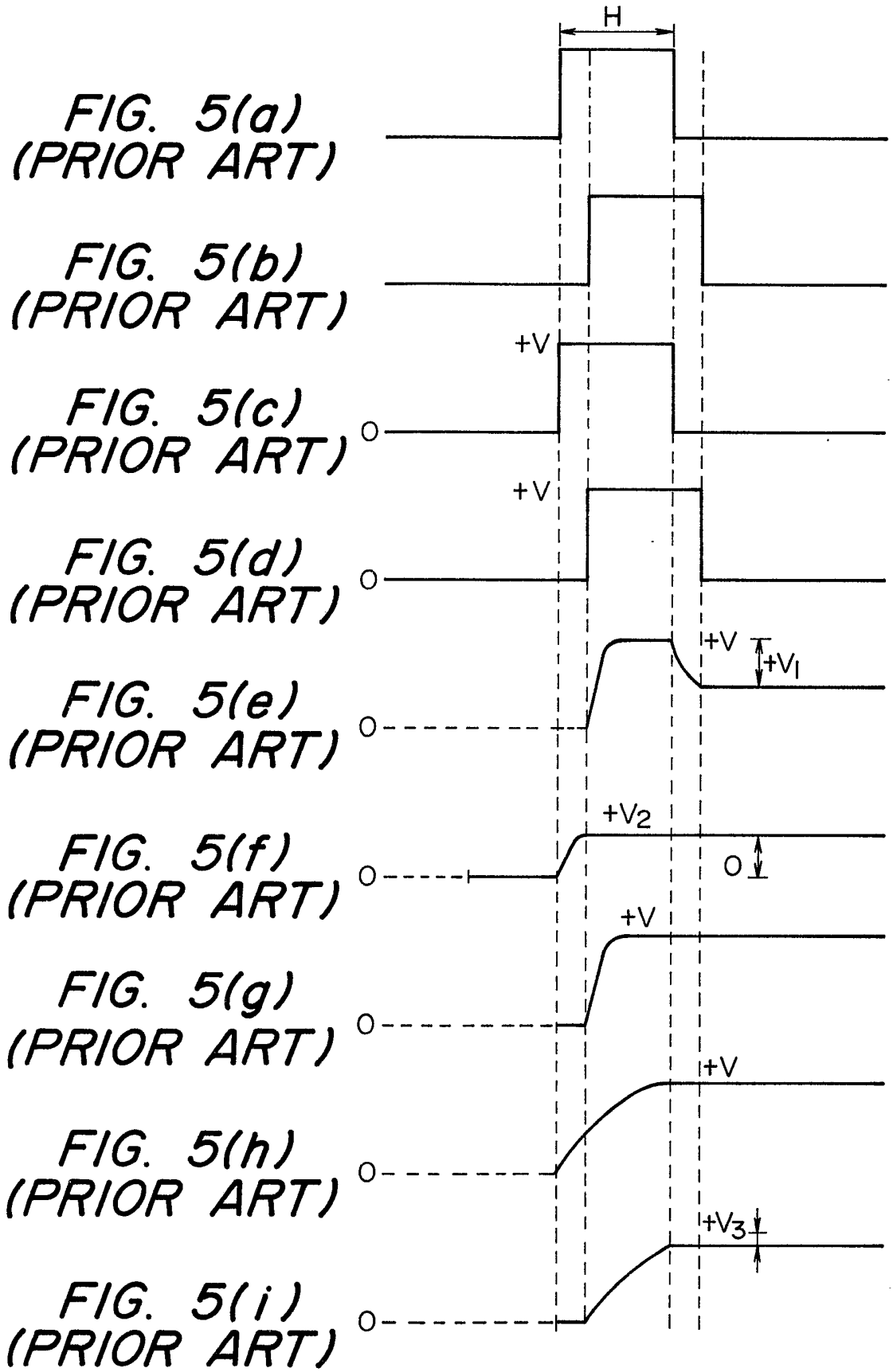


FIG. 5(a)
(PRIOR ART)

FIG. 5(b)
(PRIOR ART)

FIG. 5(c)
(PRIOR ART)

FIG. 5(d)
(PRIOR ART)

FIG. 5(e)
(PRIOR ART)

FIG. 5(f)
(PRIOR ART)

FIG. 5(g)
(PRIOR ART)

FIG. 5(h)
(PRIOR ART)

FIG. 5(i)
(PRIOR ART)

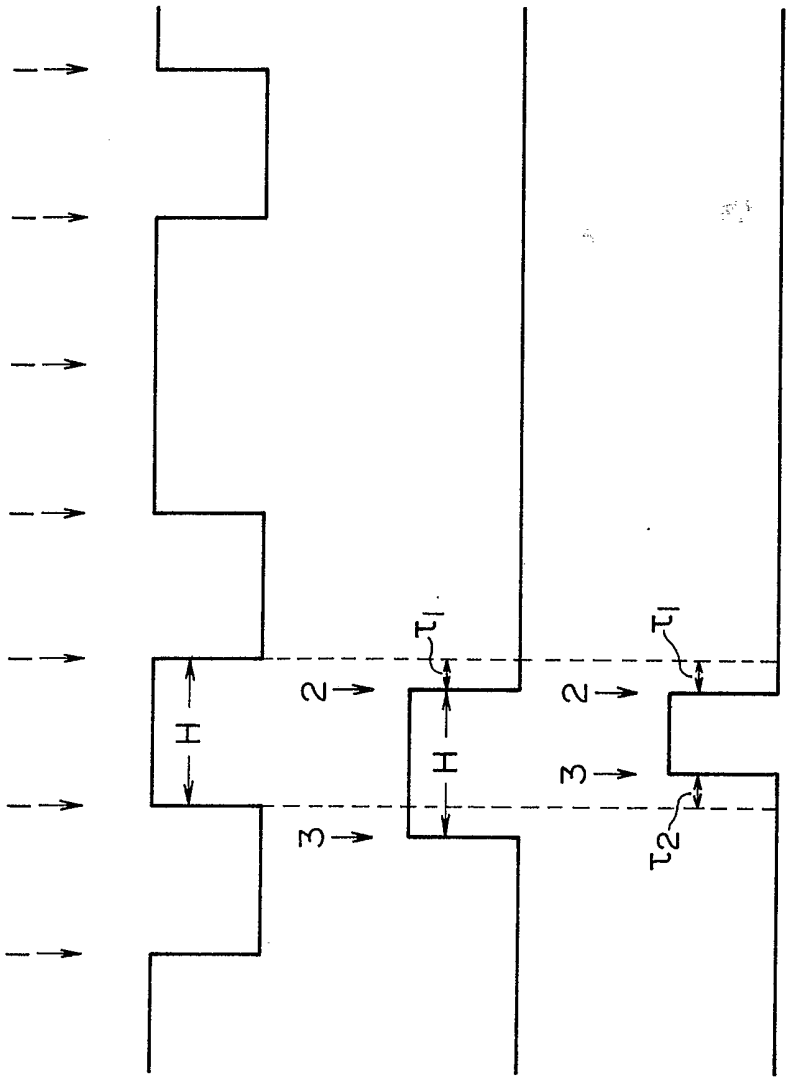


FIG. 6(a)

FIG. 6(b)

FIG. 6(c)

FIG. 7(a)

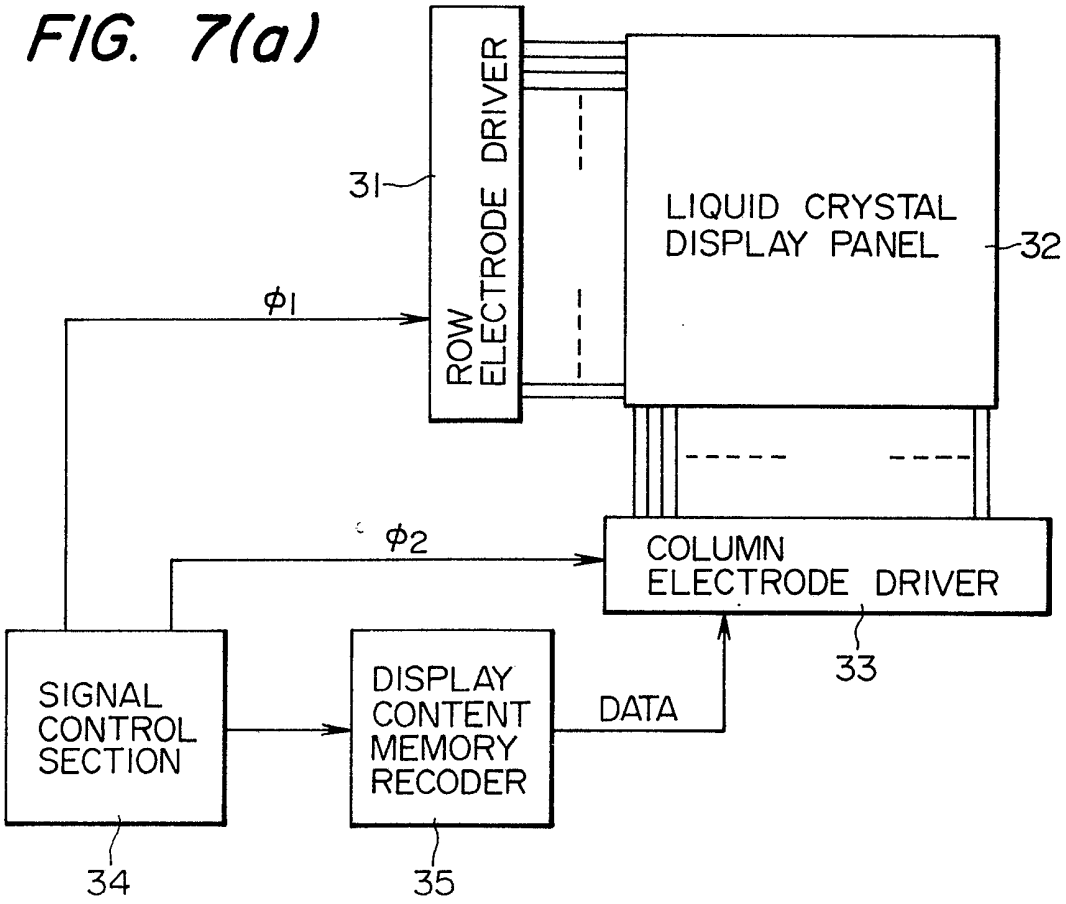


FIG. 7(b)

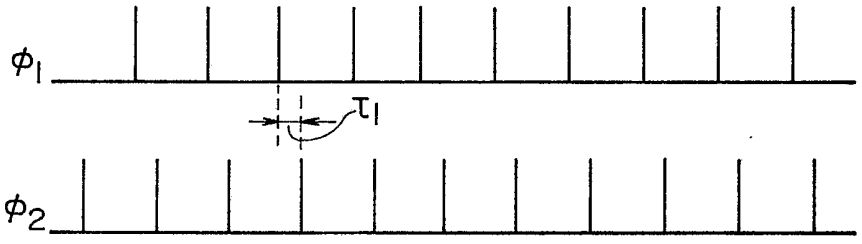


FIG. 7(c)

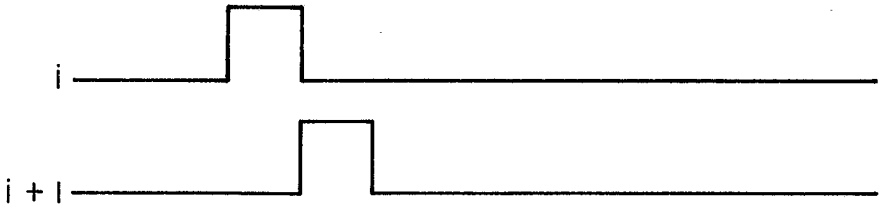


FIG. 8(a)

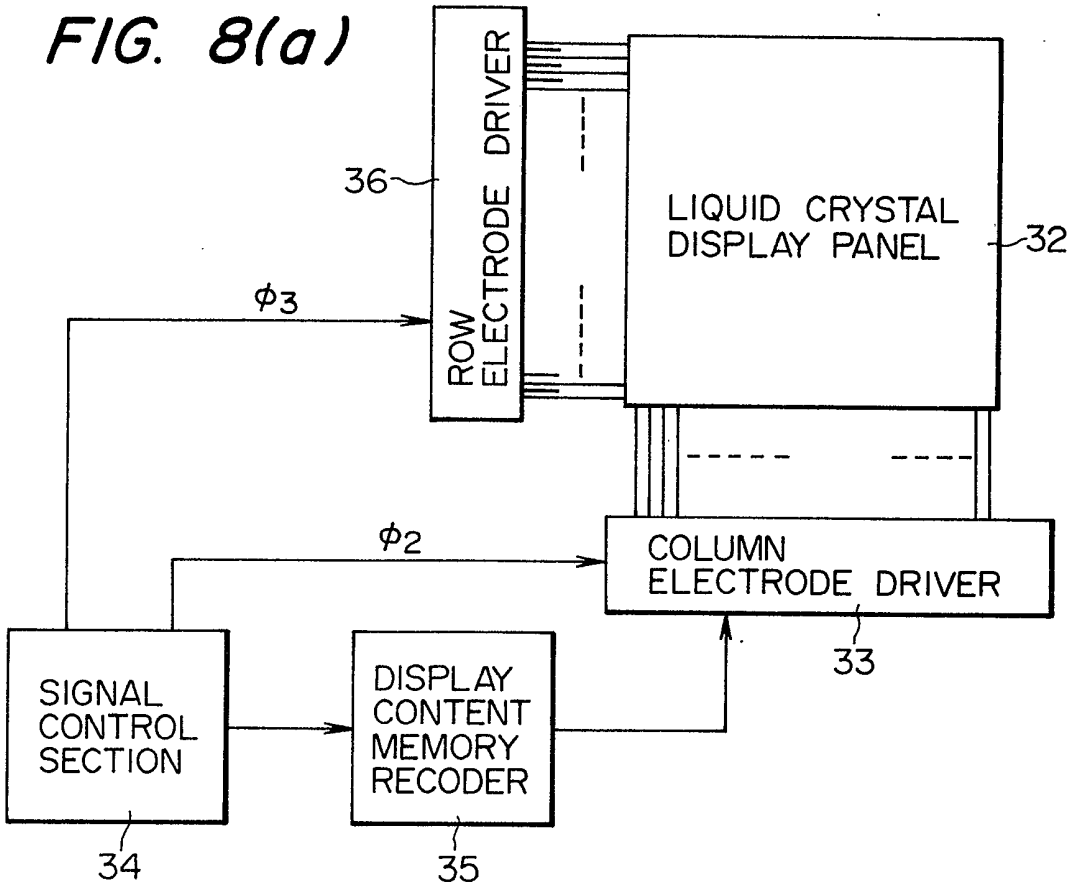


FIG. 8(b)

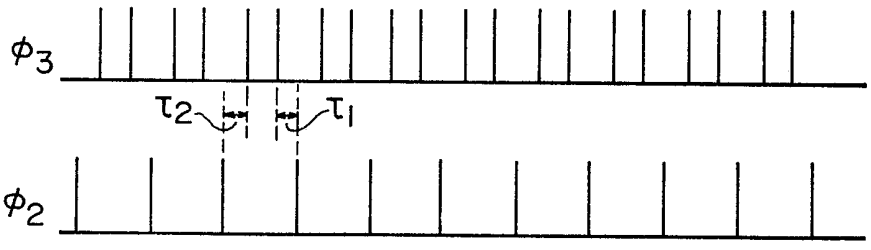
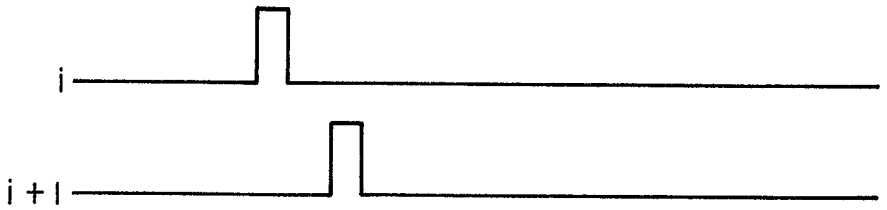


FIG. 8(c)



SPECIFICATION

Method of driving a liquid crystal display device

This invention relates to matrix type liquid crystal display devices, and more particularly to a method of driving in matrix type liquid crystal display device in which each of the picture elements in the matrix type display pattern is provided with a thin film transistor.

In a matrix type liquid crystal display with thin film transistors, the thin film transistors are connected to the liquid crystal display panel and the device can produce a high contrast display even when it is driven at a low duty ratio or duty cycle in a multiple-line multiplex driving mode. A generally well-known matrix type liquid crystal display device is shown in Fig. 1. In Fig. 1, thin film transistors 11 are connected to display picture element electrodes 12 via the drain electrodes of the thin film transistors 11. Line (row) electrodes 13 are connected to the gate electrodes 25 of the thin film transistors 11 and column electrodes 14 are connected to the source electrodes 26 of the thin film transistors. Insulating films 15 insulate the line electrodes 13 from the column electrodes 14. These line (row) and column electrodes 13 and 14 are formed between the picture element electrodes 12.

The principles of operation of the above-described liquid crystal display device will be described with reference to an equivalent circuit diagram (Fig. 2) and a drive signal waveform diagram (Fig. 3). The liquid crystal display device described below employs, for example, n-channel type thin film transistors. A scanning signal, as illustrated in Figs. 3(a) or 3(b), is applied to gate electrodes 25 (Fig. 2) via the line electrode 21 to turn on the transistors 22 for a certain period of time. Figs. 3(a) and 3(b) depict the signals which are applied to line electrodes (i) and (i—1), respectively. A data waveform signal, as illustrated in Fig. 3(c), is applied to the source electrodes 26 of the thin film transistors 22 (Fig. 2) via the column electrodes 23. The data signal voltage is raised to a value V for the time period necessary to scan a line of liquid crystals to be turned on, and it is returned to zero volts for the time period necessary to scan a line of liquid crystals to be turned off. The polarity of the voltage V changes during a scanning period when an AC type driving waveform is employed. Fig. 3(c) illustrates such a signal as applied to column electrode (j), and, in this case, the picture element at the intersection of column (j) and line (i) is turned on, while the picture elements connected to the other columns remain off. In Fig. 2, the liquid crystals 12 have capacitances 24 between the display picture element electrode 12, connected to the drain electrode 27 of the thin film transistor, and the ground electrode held at zero volts.

The picture element at the intersection of line (i) and column (j) will be described with reference to Fig. 2. When the thin film transistor 22 is turned on, a charge is applied to the capacitance 24 of the liquid crystal 12 from the column electrode through the transistor 22, and the potential of the display picture element electrode 12 is raised to +V which is a voltage equal to that of the data signal. When the transistor 22 is turned off, the charge remains on the capacitance 24 of the liquid crystal 12 and the potential of the display picture element electrodes is maintained at +V. When the transistor 22 is turned on again, the capacitance 24 of the liquid crystal is negatively charged until the potential of the display picture element electrode is —V, and the charge on the capacitance 24 is maintained for the period of time during which the transistor is kept nonconductive. Thus, a signal as shown in Fig. 3(d) is applied to the display picture element electrode, and the liquid crystal is turned on.

The operation of the picture element at the intersection of line (i+1) and column (j) will be described with respect to the description of the picture element at the intersection of line (i) in column (j). The operation of the picture element at the intersection of line (i) in column (j) requires a scanning signal to be applied to line electrode (i) in order to render the transistor at the junction of line (i) in column (j) conductive. However, a scanning signal is not applied to line (i+1) during the operation of the display picture element at the intersection of line (i+1) in column (j) and therefore the transistor at the intersection of line (i+1) in column (j) is not conductive. Because the transistor is not conductive the display picture element electrode 12 is maintained at zero volts. When the display picture element electrode 12 is maintained at zero volts, as is shown in Fig. 3(e), no voltage is applied to the liquid crystal, and accordingly the liquid crystal remains off.

As is apparent from the above description, during the operation of the above-described liquid crystal display device, even though multiplex driving is carried out, the voltage applied to the liquid crystal is equivalent to a static driving voltage.

In the above-described liquid crystal display device, the line electrodes 13 and column electrodes 14 are a metal such as aluminium or nickel, or a transparent conductive film. Because light cannot pass through the metal, the electrode width should be as small as possible but within a range limited by patterning accuracy and high device yield. In some cases the resistance of each electrode will be high enough so that it cannot be disregarded. Where the line and column electrodes are a transparent conductive film, they have a surface resistance of 10 Ω/cm^2 even if the transparent conductive film is of the highest quality. Increasing the electrode width to reduce the resistance is undesirable, because an undesirable decrease in the area of the display picture element electrodes results. Therefore, it is difficult to make the resistances of the line and column electrodes sufficiently small.

If the line electrodes 13 and the column electrodes 14 have a very high resistance as

described above, the electrode resistance coupled with the load capacitance 24, connected to the electrodes, and other stray capacitances distort the applied voltage waveform. For example, when a waveform signal, as depicted in Fig. 4(a), is applied to the electrode, it is distorted by the electrode resistance and the capacitance, as illustrated in Fig. 4(b). The distorted waveform of Fig. 4(b) is equivalent to the original signal (Fig. 4(a)) delayed by a time t_1 as illustrated in Fig. 4(c).

The effect of the delayed waveform on the display when the liquid crystal display device is driven, will be described with reference to Fig. 5. Figs. 5(a) and 5(b) depict an original scanning signal and a delayed scanning signal, respectively. When the scanning signal lags behind the data signal, as illustrated in Figs. 5(b) and 5(c) during scanning of the picture element at the intersection of line (i) and column (j), the transistor 22 is rendered conductive, the capacitance 24 associated therewith is charged to +V volts. When the transistor 22 is turned on a second time, the level of the charge on the capacitance 24 and therefore the data signal is changed from +V to zero volts, as the capacitance 24 discharges. Accordingly, the voltage of the data signal when the transistor is turned off becomes smaller than +V, as illustrated in Fig. 5(e). This voltage drop is increased in accordance with the length of the delay. In other words, the voltage drop increases as the electrode resistance and capacitance associated with the circuit gets higher. In a case where the display content is such that the picture elements on line (i+1) are also turned on, no voltage drop occurs. Similarly, the picture element at the intersection of line (i—1) and column (j) which is to be held at zero volts is charged to a voltage $+V_2$, as illustrated in Fig. 5(f). In other words, the voltage drop in the data signal associated with the picture element at line (i) and column (j) is applied to a picture element which is supposed to be turned off. When the timing of the scanning signal is delayed by the electrode resistance and capacitance, as described above, the voltage applied to each picture element changes according to or is dependent on the display content. Since the magnitude of the change depends on the positions in the display which are turned on, the display contrast is not uniform.

Now, let us consider the case where the data signal lags behind the scanning signal with reference to Figs. 5(a) and 5(d). In this case, the picture element at the intersection of line (i) and column (j), is charged to zero volts, which is the data intended for line (i—1), when the transistor is turned on and then to +V the data intended for line (i) and column (j). If, in this case, the driving condition permits quick charging through the transistor 22, then no problems will arise because charging will be carried out at all times, even when the transistor 22 is turned off, as illustrated in Fig. 5(g). However, when the charging period is longer than the scanning period H, the picture element, which should be charged to +V, as illustrated in Fig. 5(h), is charged only to an intermediate level $+V_3$, as shown in Fig. 6(i), and therefore the display contrast is once again not uniform.

In view of the above-described difficulties accompanying the conventional method of driving a matrix type liquid crystal display device, an object of this invention is to provide a method of driving a liquid crystal display device in which the display contrast is satisfactory even when the drive signal waveform is distorted by the resistances and capacitances of the line, column and display electrodes.

According to a first aspect of the present invention a method of driving a matrix type liquid crystal display device which includes a liquid crystal picture forming element at the intersection of each line electrode and column electrode and in which each liquid crystal element is provided with a thin film transistor connected to the row electrode and the column electrode, comprises applying a scanning signal to the line electrode; and applying a data signal to the column electrode, wherein the scanning signal is advanced with respect to the data signal.

According to a second aspect of the invention a method of driving a matrix type liquid crystal display device which includes a liquid crystal picture forming element at the intersection of each line electrode and column electrode and in which each liquid crystal element is provided with a thin film transistor connected to the row electrode and the column electrode, comprising applying a scanning signal having a leading edge and a trailing edge to the line electrode; and applying a data signal having a leading edge and a trailing edge to the column electrode, wherein the leading edge of the scanning signal is delayed with respect to the leading edge of the data signal.

One example of a method according to the invention will now be described with reference to Figures 6 to 8 of the accompanying drawings in which:—

Fig. 1 is a plan view of a matrix type liquid crystal display device including thin film transistors;

Fig. 2 is an equivalent circuit diagram corresponding to the device in Fig. 1;

Fig. 3, including Figs. 3(a)—3(e), is a waveform diagram associated with the conventional driving method depicting the signal supplied to the electrodes of a matrix type liquid crystal;

Fig. 4, including Figs. 4(a)—4(c), is a waveform diagram illustrating the distortion of the signal waveform caused by the resistances and capacitances of the line and column electrodes when a conventional driving method is used;

Fig. 5, including Figs. 5(a)—5(i), is a waveform diagram illustrating the shift in the signals supplied to the electrodes of a matrix type liquid crystal display device when the waveform distortion associated with the conventional driving method is taken into account;

Fig. 6, including Figs. 6(a)—6(c) is a waveform

diagram of the signals supplied to the electrodes of a matrix type liquid crystal display device according to an embodiment of the present invention; and

Fig. 7, including Figs. 7(a)—7(c), and 8, including Figs. 8(a)—8(c), are block diagrams and waveform diagram illustating examples of the driving circuitry and the waveforms associated therewith according to the present invention.

The driving method according to the present invention shifts the timing of the scanning signal with respect to the timing of the data signal in advance, to eliminate the effect caused by the delay of the waveform. The driving waveforms are as illustrated in Fig. 6, where Fig. 6(a) depicts a data signal which is applied to column electrodes, having equal intervals H with signal leading edge timing 1 and where Figs. 6(b) and 6(c) depict scanning signal waveforms.

In Fig. 6(b) the scanning signal waveform in the transistor 22 turns off at time 2 which occurs earlier than the trailing edge time 1 of the data signal (Fig. 6(a)). The amount of change is determined by the maximum delay time T_1 which can be estimated from the time constant of the combined resistance and capacitance of the line electrodes. In the scanning signal waveform (Fig. 6(b)), the leading edge time 3, at which the transistor is turned on, is not particularly limited by a condition that the capacitance 24 be charged through the transistor 22 quickly, and therefore, the interval between times 2 and 3 can be set to a maximum value H which is determined from the number of scanning lines. The data switching time and the scanning timing intervals are equal while the scanning timing signal leading edge (Fig. 6(b)) occurs earlier, by T_1, than the data switching timing signal leading edge (Fig. 6(a)).

When the charging of the capacitance occurs slowly and the delay of the data signal waveform with respect to the scanning signal waveform would cause a non-uniform display problem, leading edge 3 of the scanning signal trails the leading edge 1 of the data signal by an expected delay time T_2, as illustrated in Fig. 6(b), and the effect caused by the delay of the data signal waveform can be eliminated.

Fig. 7(a) is a block diagram of a drive circuit using the scanning waveforms of Fig. 6 according to the principle described above. Figs. 7(b) and 7(c) are waveform diagrams for a description of the operation of Fig. 7(a). In Fig. 7(a), a liquid crystal panel having line electrodes and column electrodes form an electrode matrix, and thin film transistors are provided at the intersection of the line and column electrodes. Suitable thin film transistors can be found in Japanese Patent Application No. 230,070 by Takechi et al. filed on December 29, 1982 and the corresponding U.S. application filed concurrently therewith, both applications being assigned to the present applicant. The line electrodes and the column electrodes are connected to electrode drivers 31 and 33 respectively, so that drive voltages are applied to the proper electrodes. The line electrode driver 31 comprises a standard shift register with a number of stages equal to the number of scanning lines. In the line electrode driver 31, the scanning waveform is shifted by a clock pulse $\emptyset_1$ and applied to the line electrodes. The column electrode driver 33 comprises a standard shift register and standard latch circuits. In the column electrode driver 33 data is latched with the aid of a clock pulse $\emptyset_2$ and applied to the column electrodes.

A signal control section 34 outputs the clock pulses $\emptyset_1$ and $\emptyset_2$, and applies a data signal through a display content memory/decoder 35 to the column electrode driver 33. The above-described circuit is substantially the same as conventional drive circuits, however, the timing of the clock pulse $\emptyset_1$ and the timing of the clock pulse $\emptyset_2$, ($\emptyset_2$ being the same in the prior art) are shifted as much as T_1 with respect to each other, as shown in Fig. 7(b), resulting in a driving method in which the scanning waveform leads the data waveform by T_1. Fig. 7(c) illustrates scanning waveforms for the line electrodes (i) and (i+1).

Fig. 8(a) is a block diagram of a drive circuit using the scanning waveform of Fig. 6(c), and Figs. 8(b) and 8(c) are waveform diagrams for a description of the operation. The drive circuit is different from the drive circuit in Fig. 7 because the circuit in Fig. 8(a) uses a different electrode line driver 36. The line electrode driver 36 comprises a shift register which has twice as many stages as scanning lines. In the line electrode driver 36, the scanning waveform is shifted by clock pulse $\emptyset_3$ which is applied to the line electrodes of every other stage. Accordingly, the frequency of the clock pulse $\emptyset_3$ is twice that of clock pulse $\emptyset_1$ or $\emptyset_2$, and its timing is as illustrated in Fig. 8(b). Fig. 8(c) illustrates the scanning signal waveforms for line electrodes (i) and (i+1) in which the leading edge of the scanning signal is delayed with respect to the leading edge of the data signal, and the trailing edge of the scanning signal is advanced with respect to the trailing edge of the data signal. With the above-described drive circuit, the drive method as described with reference to Fig. 6(c) can be performed by controlling the timing of the clock pulse $\emptyset_3$.

As is apparent from the above description, the invention provides an effective driving method which eliminates the effects caused by distortion of the signal waveform which in turn is caused by the resistances and capacitances of the electrodes. The method is very useful for driving a large capacity X—Y matrix type liquid crystal display device.

Claims

1. A method of driving a matrix type liquid crystal display device which includes a liquid crystal picture forming element at the intersection of each line electrode and column electrode and in which each liquid crystal element is provided with a thin film transistor connected to the row electrode and the column electrode, the method

comprising applying a scanning signal to the line electrode; and applying a data signal to the column electrode, wherein the scanning signal is advanced with respect to the data signal.

2. A method according to claim 1, wherein a trailing edge of the scanning signal is advanced with respect to a trailing edge of the data signal.

3. A method according to claim 2, wherein the pulse width of the scanning signal is equal to the pulse width of the data signal.

4. A method according to claim 1, wherein the leading edge of the scanning signal is delayed with respect to the leading edge of the data signal.

5. A method according to claim 1, wherein the advancement of the scanning signal is determined in accordance with the resistor-capacitor time constant associated with the capacitance formed by the liquid crystal element and the line electrode and the resistance of the line electrode.

6. A method of driving a matrix type liquid crystal display device which includes a liquid crystal picture forming element at the intersection of each line electrode and column electrode and in which each liquid crystal element is provided with a thin film transistor connected to the line electrode and the column electrode, the method comprising applying a scanning signal having a leading edge and a trailing edge to the line electrode; and applying a data signal having a leading edge and a trailing edge to the column electrode, wherein the leading edge of the scanning signal is delayed with respect to the leading edge of the data signal.

7. A method according to claim 6, wherein the scanning signal trailing edge is advanced with respect to the data signal trailing edge.

8. A method according to claim 6, wherein the delay of the scanning signal leading edge is determined in accordance with the resistor-capacitor time constant associated with the capacitance formed by the liquid crystal element and the line electrode and the resistance of the line electrode.

9. A method according to claim 7, wherein the advancement of the scanning signal trailing edge is determined in accordance with the resistor-capacitor time constant associated with the capacitance formed by the liquid crystal element and the line electrode and the resistance of the line electrode.

10. A method according to claim 7, wherein the advancement of the scanning signal trailing edge is determined in accordance with a charging rate associated with a capacitance formed by the liquid crystal element.

11. A method according to claim 6, wherein the delay of the scanning signal leading edge is determined in accordance with the resistor-capacitor time constant associated with the capacitance formed by the liquid crystal element and the line electrode and the resistance of the line electrode and the rate of change associated with the capacitance formed by the liquid crystal element.

12. A method of driving a matrix type liquid crystal display device, substantially as described with reference to either of the examples described with reference to Figures 6 to 8 of the accompanying drawings.

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