

LIQUID CRYSTAL APPARATUS

FIELD OF THE INVENTION AND RELATED ART

The present invention relates to a liquid crystal apparatus including a ferroelectric liquid crystal device and a multiplexing drive means.

5 In recent years, the use of a bistable liquid crystal device has been proposed as an improvement to the conventional TN-liquid crystal device by Clark and Lagerwall (U.S. Patent No. 4,367,924, etc.). As the bistable liquid crystal, a ferroelectric liquid crystal having a chiral smectic C phase (SmC*) or H phase (SmH*) is generally used. The liquid crystal shows bistable states including a first and a second optically stable state in response to an electric field, so that the liquid crystal is oriented to, e.g., the first optically stable state in response to one electric field vector and to the second optically stable state in response to the other electric field vector. Further, the liquid crystal very quickly responds to an applied electric field to be oriented to either one of the two stable states and retains the resultant state in the absence of an electric field. By utilizing these properties, it is possible to attain a substantial improvement in problems accompanying the use of the conventional TN-type liquid crystal device.

15 Further, many proposals have been made with respect to a driving method for multiplexing drive of such a bistable ferroelectric liquid crystal device, including those disclosed in U.S. Patents Nos. 4655561, 4638310, 4715688, 4701026, 4725129, 4770502, 4850676, etc.

However these multiplexing drive methods proposed in the above patents involve the following problems.

20 (1) The response speed of the liquid crystal per se is faster than that of a conventional TN-liquid crystal, but the frame frequency in matrix drive is low.

(2) The range of voltage value or pulse duration of a drive pulse allowable for matrix drive, i.e., the drive margin, is narrow.

As an improvement with respect to the above problem (1), the above-mentioned U.S. Patent No. 25 4770502 has proposed a driving method wherein selection terms for scanning lines are overlapped to each other to provide an increased frequency. This method is accompanied with a tendency that the drive margin (2) is further decreased, so that it has been difficult to satisfy a high frame frequency and a wide drive margin in combination by the conventional methods.

30

SUMMARY OF THE INVENTION

An object of the present invention is to provide a ferroelectric liquid crystal apparatus which satisfies a higher frame frequency in multiplexing drive of a ferroelectric liquid crystal device while retaining a sufficient drive margin.

35 According to the present invention, there is provided a liquid crystal apparatus, comprising: a ferroelectric liquid crystal device comprising an electrode matrix including a plurality of scanning lines and a plurality of data lines intersecting with the scanning lines, and a ferroelectric liquid crystal disposed between the scanning lines and data lines, and
40 drive means for sequentially applying a scanning signal to the scanning lines for selecting a particular scanning line, and for applying data signals for the pixels on the selected scanning line to the data lines, wherein each of the data signals has a plurality of pulses including a pulse in a controlled phase and a pulse in an auxiliary phase, and the scanning signal for the selected scanning line has a compensation pulse for compensating the pulse in the auxiliary phase of a data signal for a pixel on the selected scanning line.
45

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

50

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a waveform diagram showing a set of driving signal waveforms used in an embodiment of the liquid crystal apparatus according to the present invention.

Figures 2A and 2B are time charts each showing time-serial waveforms based on unit drive signals

shown in Figure 1.

Figure 3 is a schematic view showing a display pattern on a liquid crystal device.

Figures 4 and 5 are time charts each showing time-serial waveforms based on drive signals used in conventional methods.

5 Figure 6 is a block diagram of a liquid crystal display apparatus and a graphic controller.

Figure 7 is a time chart showing time correlation for image data communication between the liquid crystal display apparatus and the graphic controller.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

10

Figure 1 shows a set of driving signal waveforms used in an embodiment of the liquid crystal apparatus according to the present invention, in which a selection signal waveform is shown at (a), and data signal waveforms corresponding to "white" and "black" image data are shown at (b) and (c), respectively. Further, a voltage of, e.g., zero (not shown) is applied to scanning lines at the time of non-selection.

15 Referring to the waveform at Figure 1(b), a phase having a pulse duration t_2 and a voltage value V_5 is a control phase, and phases having a pulse duration t_3 and a voltage value $-V_4$ are auxiliary phases. As described above, by using a data signal having these pulse phases, an image defect, such as flicker at the time of non-selection, can be alleviated. The selection signal waveform at Figure 1(a) comprises a clear or erasing phase having a pulse duration t_1 and a voltage value V_1 , a control phase having a pulse duration t_2 and a voltage value $-V_2$, and an auxiliary phase having a pulse duration t_3 and a voltage value V_3 , which is
20 a phase for compensating an auxiliary phase of the data signal. Herein, the voltage V_3 is set to satisfy $0 < V_3 < V_1$ and may preferably satisfy $|V_3| = |V_4|$. The provision of this compensation phase is a characteristic of the present invention, by which the above-mentioned drive margin is remarkably improved.

25 Further, it is preferred that all the pixels on a selected scanning line are once simultaneously cleared into a black state.

Figures 2A and 2B respectively show a time-serial waveform for providing a display as shown in Figure 3 based on unit drive signals shown in Figure 1.

Referring to each of Figures 2A and 2B, at $S_1 - S_4$ are shown scanning signal waveforms applied to scanning lines $s_1 - s_4$ in Figure 3, at I_1 and I_2 are shown data signal waveforms applied to data lines i_1 and i_2 , and at $(I_1 - S_3)$ and $(I_2 - S_2)$ are shown a combined waveform of the data signal waveform I_1 and scanning signal waveform S_3 and a combined waveform of the data signal waveform I_2 and scanning signal waveform S_2 , respectively. Particularly, the sequence shown in Figure 2A is preferred so that a lower frame frequency can be set.

35 A specific embodiment driven at a duty factor of 1/400 at room temperature provided an increased frame frequency of 1.3 times and an increased drive margin by about 10 % compared with a conventional drive embodiment shown in Figure 4. Further, compared with a conventional drive embodiment shown in Figure 5, an increased drive margin by about 50 % was attained.

In the embodiment shown in Figure 1, it is preferred that the scanning signal (scanning selection signal) shown at Figure 1(a) have pulse durations t_1, t_2 and t_3 satisfying $t_1:t_2:t_3 = 3$ or more : 2 or more : 1, preferably 5-3 : 3-2 : 1, and peak values V_1 and V_2 satisfying $|V_1| = |V_2| > 2|V_3|$, preferably $|V_1| = |V_2| > 2|V_3|$ to 4 $|V_3|$.
40

Figures 4 and 5 respectively show time-serial waveforms used in a driving embodiment outside the present invention, in which at $S_1 - S_4$ are shown scanning signals applied to scanning lines $s_1 - s_4$, at I_1 and I_2 are shown data signals applied to data lines i_1 and i_2 , and at $(I_1 - S_3)$ and $(I_2 - S_2)$ are shown combinations of I_1 and S_3 and I_2 and S_2 , respectively, for providing a display pattern as shown in Figure 3. The drive waveforms are used in a type of driving method wherein all the pixels on a selected scanning line are once written in "black" and then retained in "black" or written in "white" selectively depending on given data. The drive waveforms are designed so as to alleviate "flickering" at the time of matrix drive, but the waveforms shown in Figure 4 are accompanied with a low frame frequency, and the waveforms shown in
50 Figure 5 are accompanied with a small drive margin.

Figure 6 is a block diagram showing an arrangement of a ferroelectric liquid crystal display apparatus 601 and a graphic controller 602 provided in an apparatus body of, e.g., a personal computer as a source of supplying display data. Figure 7 is a time chart for communication of image data.

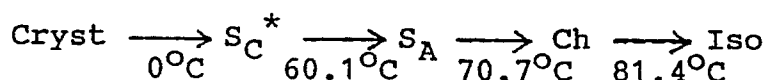
55 A display panel 603 comprises a matrix electrode structure composed of 1120 scanning electrodes and 1280 data electrodes respectively disposed on a pair of glass plates and subjected to an aligning treatment, and a ferroelectric liquid crystal disposed between the glass substrates. The scanning electrodes (lines) and data electrodes (lines) are connected to a scanning line drive circuit 604 and a data line drive circuit 605, respectively.

Hereinbelow, the operation will be explained with reference to the figures. The graphic controller 602 supplies scanning line address data for designating a scanning line and image data (PD0 - PD3) on the scanning line designated by the address data to a display drive circuit 604/605 (composed of a scanning line drive circuit 604 and a data line drive circuit 605) of the liquid crystal display apparatus 601. In this embodiment, the image data comprising the scanning line address data and the display data are transferred through the same transmission line, so that it is necessary to differentiate the above-mentioned two types of data. For the differentiation, a signal AH/DL is used. The AH/DL signal at a high level means scanning line address data, and the AH/DL signal at a low level means display data.

In the liquid crystal display apparatus 601, the scanning line address data are extracted from transferred image data PD0 - PD3 by a drive control circuit 611 and then supplied to the scanning line drive circuit 604 in synchronism with a time for driving a designated scanning line. The scanning line address data are inputted to a decoder 606 in the scanning line drive circuit 604, and a designated scanning line in the display panel 603 is driven by a scanning signal generating circuit 607 with the aid of the decoder 606. On the other hand, the display data are introduced to a shift register 608 in the data line drive circuit 605 and shifted by a unit of 4 pixel data based on a transfer clock signal. When the shift of display data for one horizontal scanning line is completed by the shift register 608, the display data for 1280 pixels are transferred to a line memory disposed in parallel, memorized for a period of one horizontal scanning and are supplied to the respective data lines as display data signals through a data signal generating circuit 610.

Further, in this embodiment, the drive of the display panel 603 in the liquid crystal display apparatus 601 is not synchronized with the generation of the scanning line address data and display data in the graphic controller 602, so that it is necessary to synchronize the apparatus 601 and 602 at the time of image data transfer. A signal SYNC is in charge of the synchronization and is generated in the drive control circuit 611 in the liquid crystal display apparatus 601 at each one horizontal scanning period. The graphic controller 602 always monitors the SYNC signal, and transfers image data when the SYNC signal is at a low level and does not effect transfer after completing transfer of image data for one horizontal scanning line when the SYNC signal is at high level. More specifically, referring to Figure 7, the graphic controller 602 immediately sets the AH/DL signal at high level and starts transfer of image data for one horizontal scanning line when it detects that the SYNC signal is at low level. The drive control circuit 611 in the liquid crystal display apparatus 601 set to the SYNC signal at high level during the image data transfer period. When the writing in the display panel 603 is completed after a prescribed one horizontal scanning period, the drive controller circuit (FLCD controller) 611 returns the SYNC signal to the low level so that it can receive image data for a subsequent scanning line.

As an example of a ferroelectric liquid crystal, a mixture of ester compounds and pyrimidine compounds showing the following phase transition series may be used in the present invention.



In the present invention, the data signal used has an auxiliary phase which alleviates flicker, etc., of an image but can increase the tendency of an unexpected inversion of a display state thereby, while the scanning signal has a pulse phase for compensating an ill effect of the pulse in the auxiliary phase of the data signal, whereby the drive margin is remarkably improved to provide a room for increasing the frame frequency so that both the drive margin and the frame frequency are increased.

As described above, by providing a scanning signal waveform with a compensation phase, an increased speed and an increased drive margin are attained to provide remarkably improved driving characteristics.

A liquid crystal apparatus includes: a ferroelectric liquid crystal device comprising an electrode matrix including a plurality of scanning lines and a plurality of data lines intersecting with the scanning lines, and a ferroelectric liquid crystal disposed between the scanning lines and data lines, and drive means for sequentially applying a scanning signal to the scanning lines for selecting a particular scanning line, and for applying data signals for the pixels on the selected scanning line to the data lines; wherein each of the data signals has a plurality of pulses including a pulse in a controlled phase and a pulse in an auxiliary phase, and the scanning signal for the selected scanning line has a compensation pulse for compensating the pulse in the auxiliary phase of a data signal for a pixel on the selected scanning line.

Claims

1. A liquid crystal apparatus, comprising:
a ferroelectric liquid crystal device comprising an electrode matrix including a plurality of scanning lines and a plurality of data lines intersecting with the scanning lines, and a ferroelectric liquid crystal disposed between the scanning lines and data lines, and
5 drive means for sequentially applying a scanning signal to the scanning lines for selecting a particular scanning line, and for applying data signals for the pixels on the selected scanning line to the data lines, wherein each of the data signals has a plurality of pulses including a pulse in a controlled phase and a pulse in an auxiliary phase, and the scanning signal for the selected scanning line has a compensation pulse for compensating the pulse in the auxiliary phase of a data signal for a pixel on the selected scanning
10 line.
2. An apparatus according to Claim 1, wherein said scanning signal comprises at least three pulses of alternating polarities with respect to the voltage level of a non-selected scanning line, and a third pulse in the at least three pulses constitutes the compensation pulse.
3. An apparatus according to Claim 1, wherein said scanning signal comprises at least three pulses of
15 alternating polarities with respect to the voltage level of a non-selected scanning line, a first pulse and a third pulse in the at least three pulses are of the same polarity, and the third pulse constitutes the compensation pulse.
4. An apparatus according to Claim 1, wherein said scanning signal comprises at least three pulses of alternating polarities with respect to the voltage level of a non-selected scanning line, and a last pulse in the
20 at least three pulses constitutes the compensation pulse.
5. An apparatus according to Claim 1, wherein said scanning signal comprises at least three pulses of alternating polarities with respect to the voltage level of a non-selected scanning line, a first pulse and a last pulse in the at least three pulses are of the same polarity, and the last pulse constitutes the compensation pulse.
6. An apparatus according to Claim 1, wherein the pulse in the control phase and the pulse in the
25 auxiliary phase of a data signal have mutually opposite polarities with respect to the voltage level of a non-selected scanning line.
7. An apparatus according to Claim 1, wherein the auxiliary phase is disposed before and after the control phase and each has a duration which is a half that of the control phase.
8. An apparatus according to Claim 1, wherein said drive means includes a means for applying a
30 clearing phase sufficient to erase a pixel prior to a pulse in the control phase through a scanning line.
9. An apparatus according to Claim 1, wherein said drive means includes a means for applying a clearing pulse sufficient to erase all the pixels on a selected scanning line prior to the control phase of data signals for the pixels on the selected scanning line.
10. An apparatus according to Claim 1, wherein said drive means includes a means for applying a
35 clearing pulse sufficient to erase all the pixels on a selected scanning line prior to the control phase of data signals for the pixels on the selected scanning line and after the commencement of application of a pulse in the control phase of data signals for the pixels on a scanning line to which a scanning signal is applied immediately prior to application of the scanning signal applied to the selected scanning line.
11. An apparatus according to Claim 8, wherein the pixel supplied with the clearing pulse is erased into
40 a black state.

45

50

55

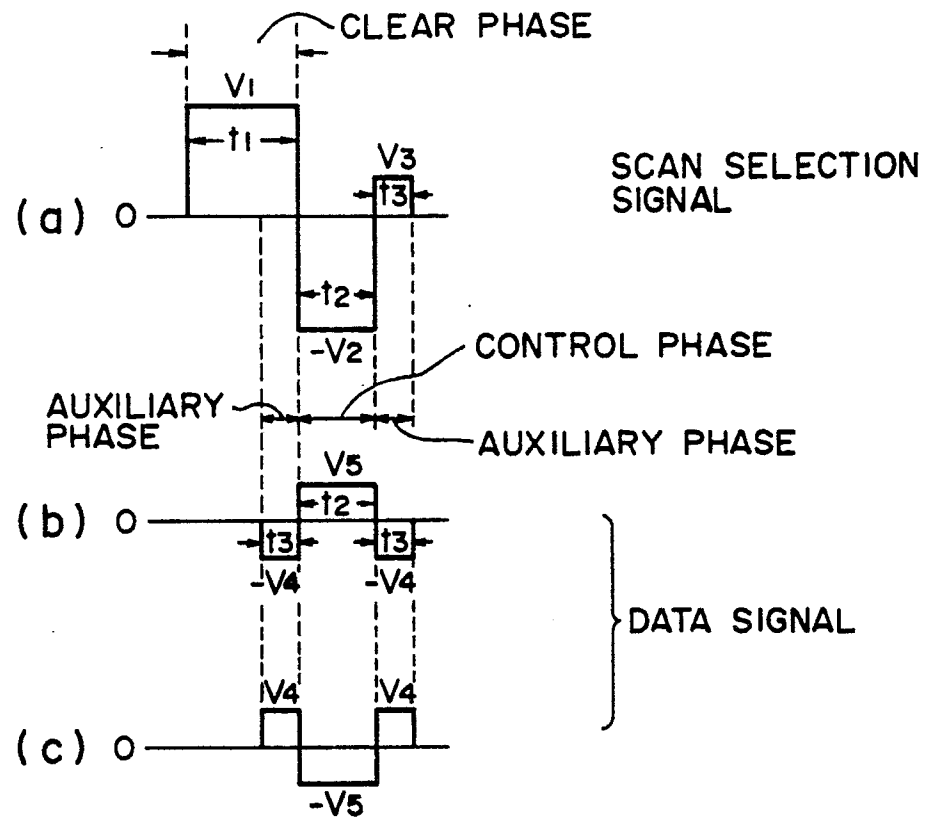


FIG. 1

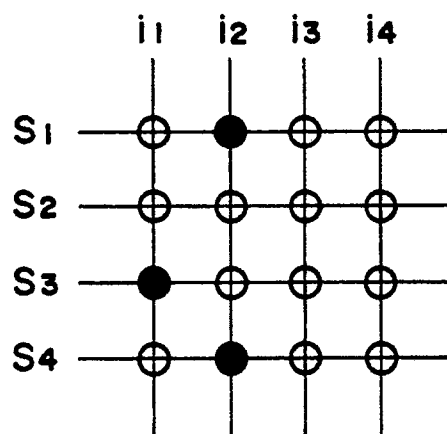


FIG. 3

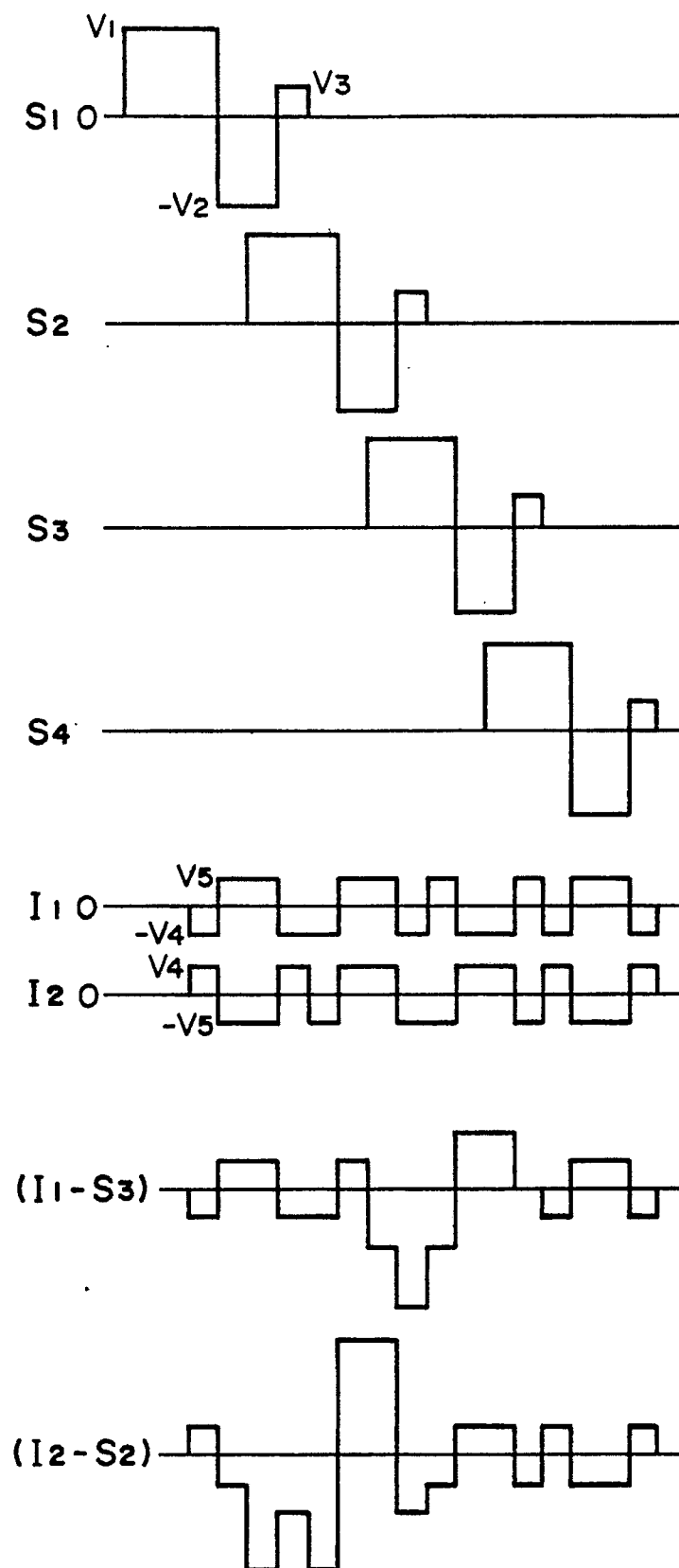


FIG. 2A

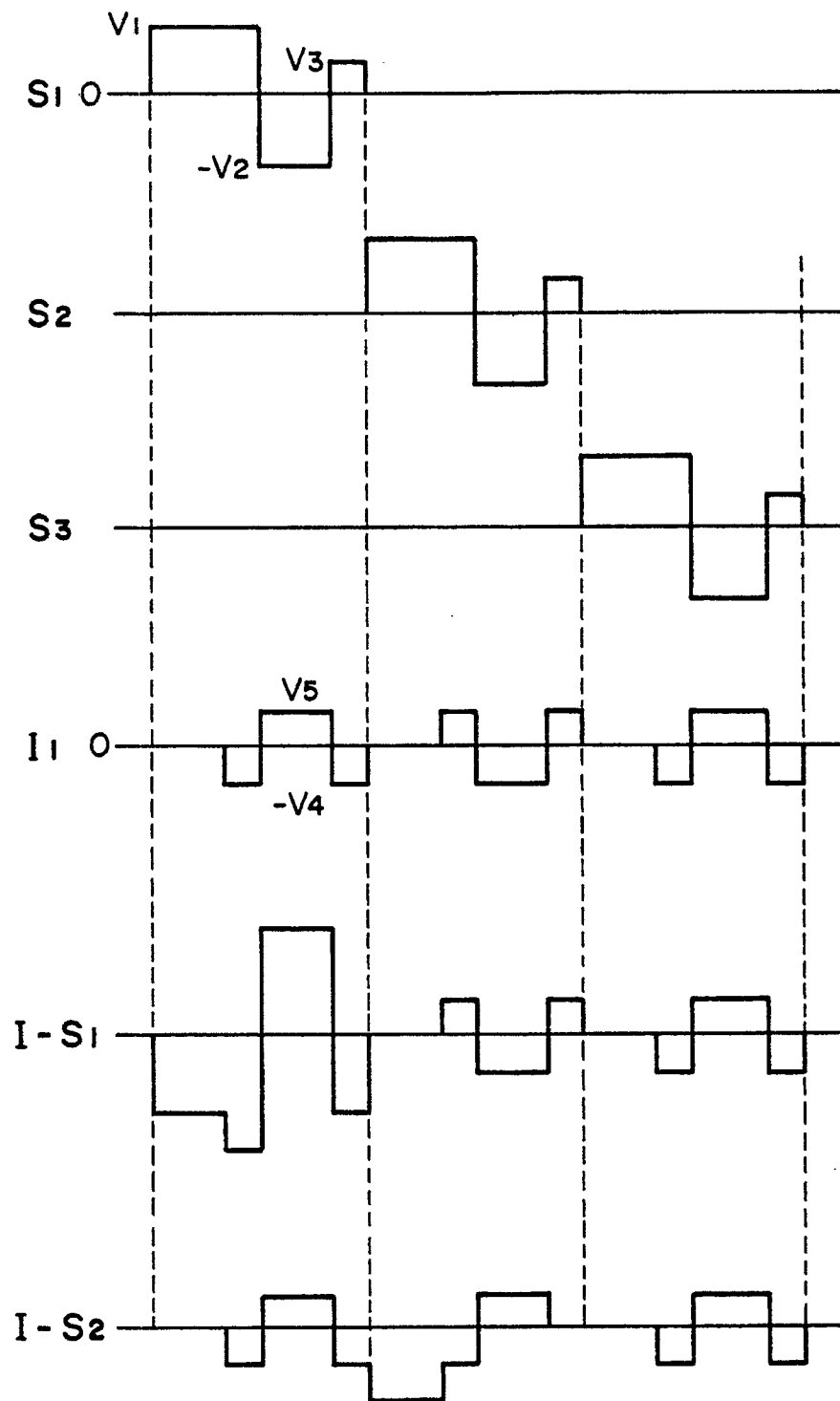


FIG. 2B

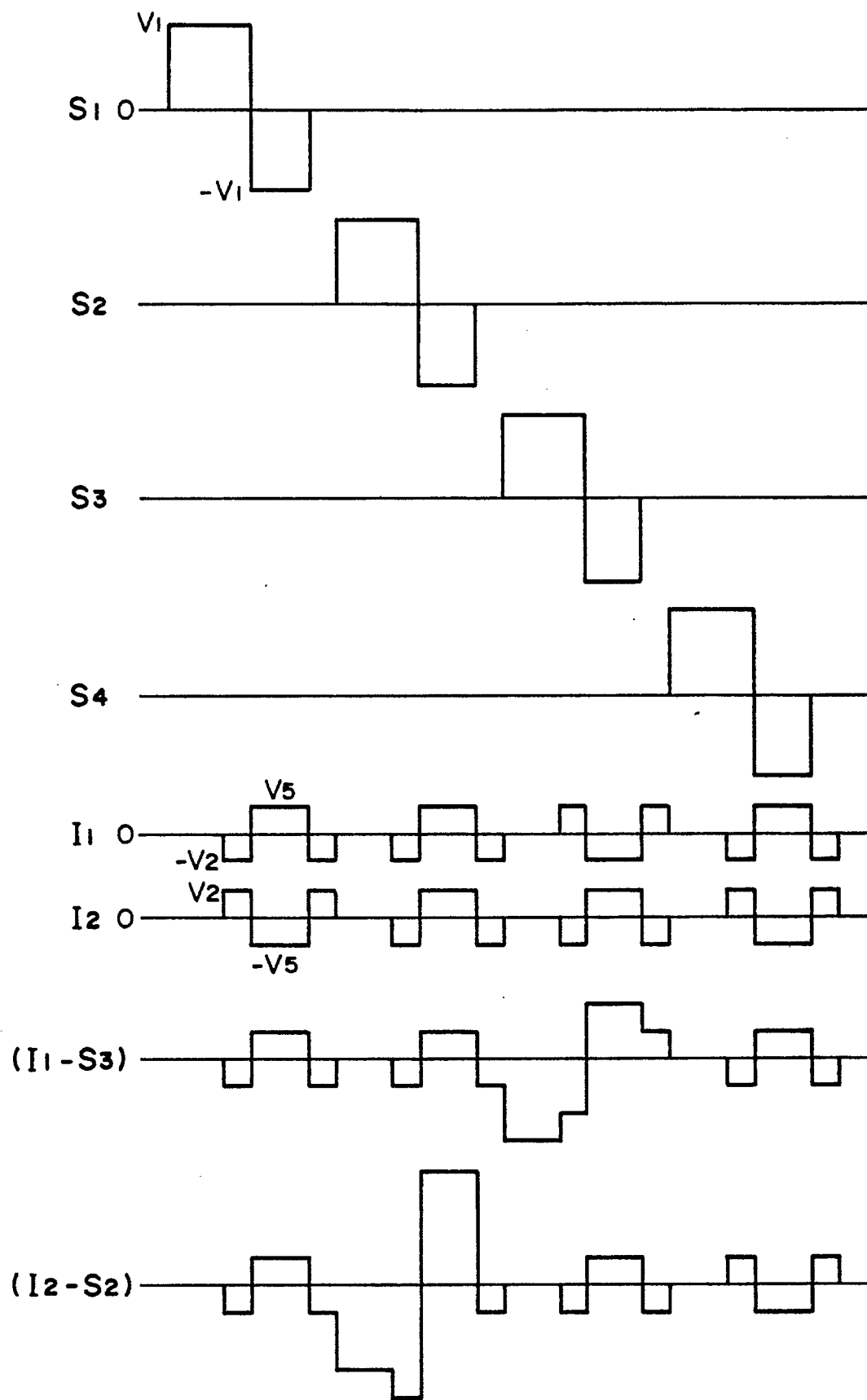


FIG. 4

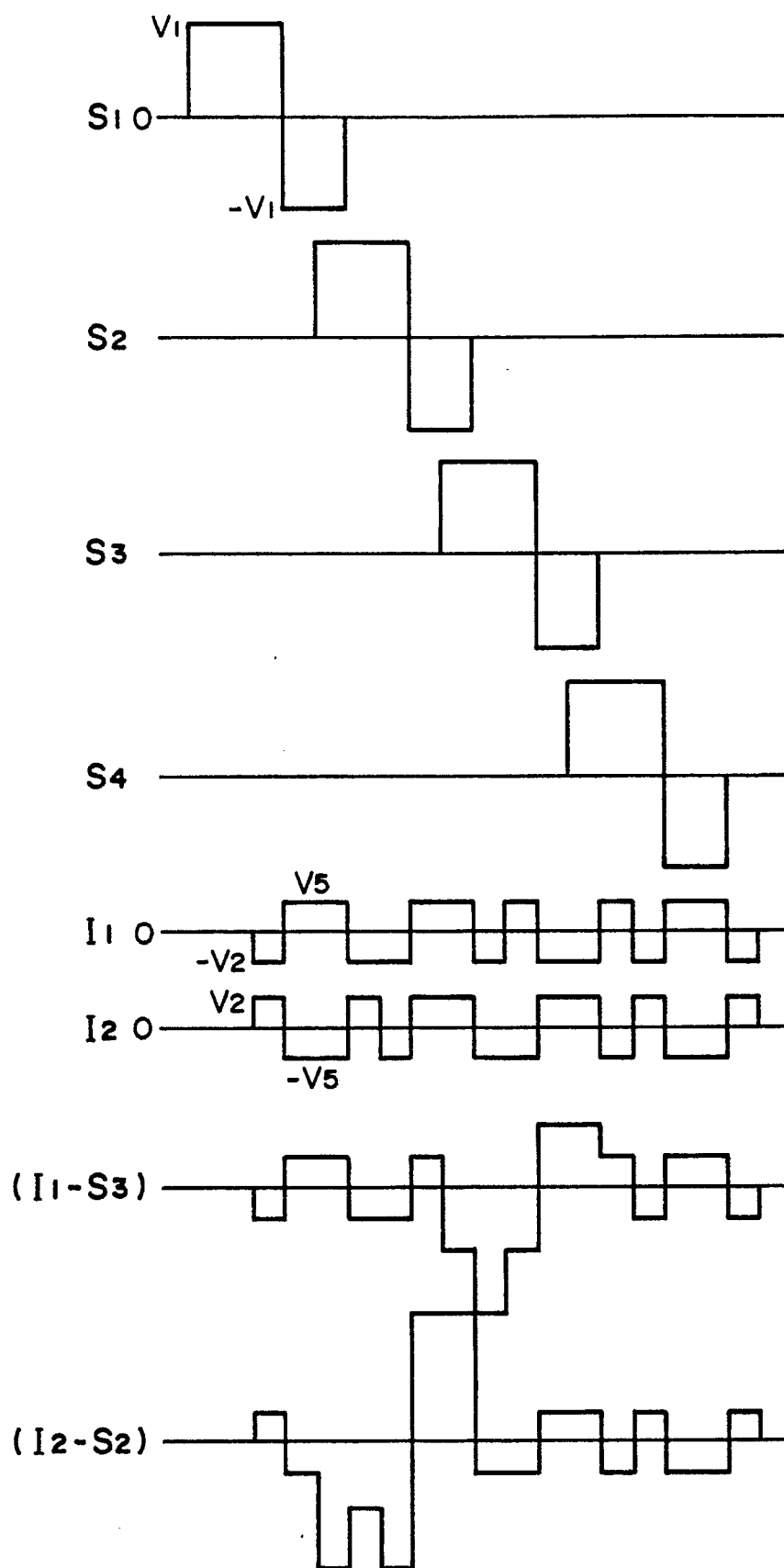


FIG. 5

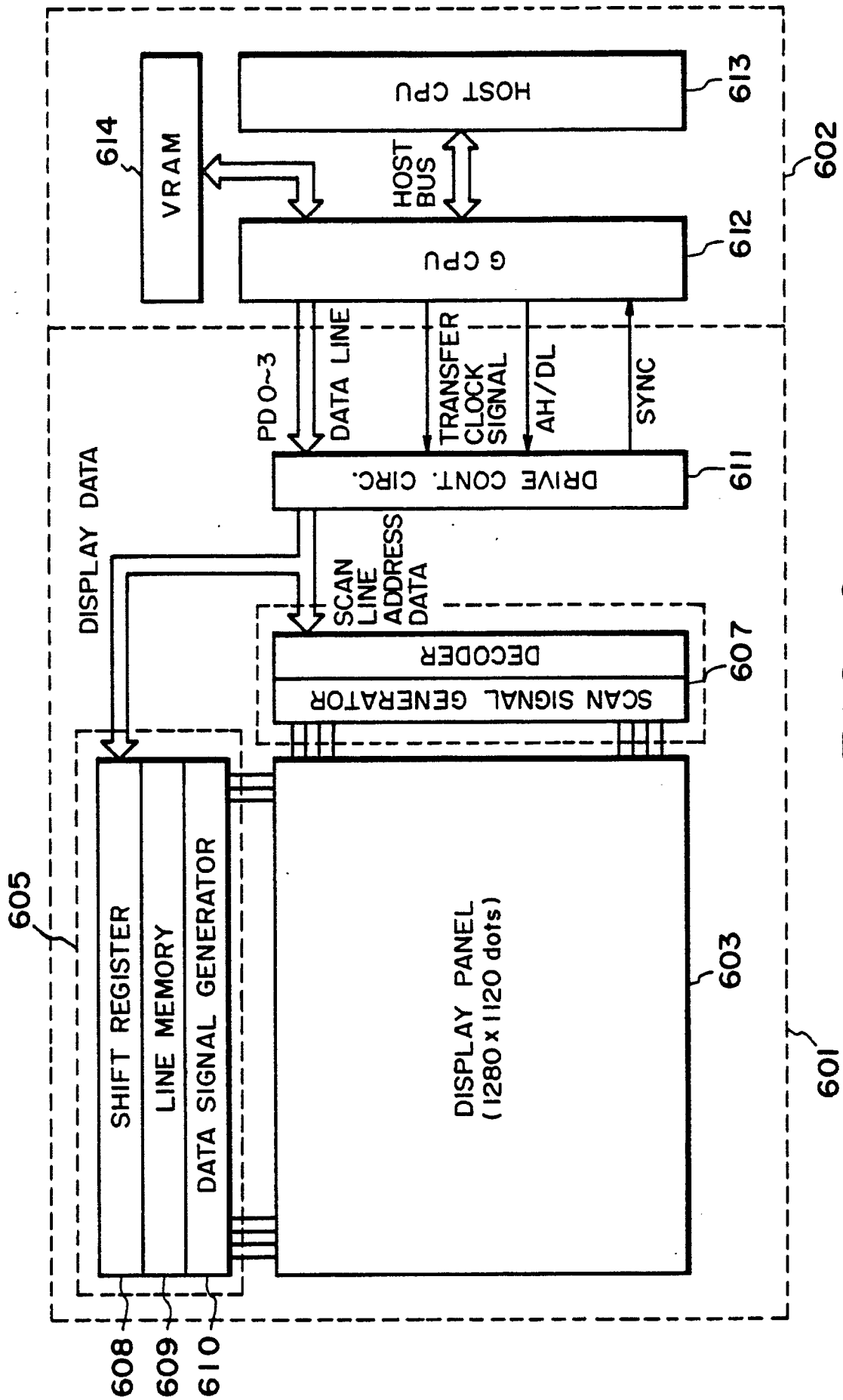


FIG. 6

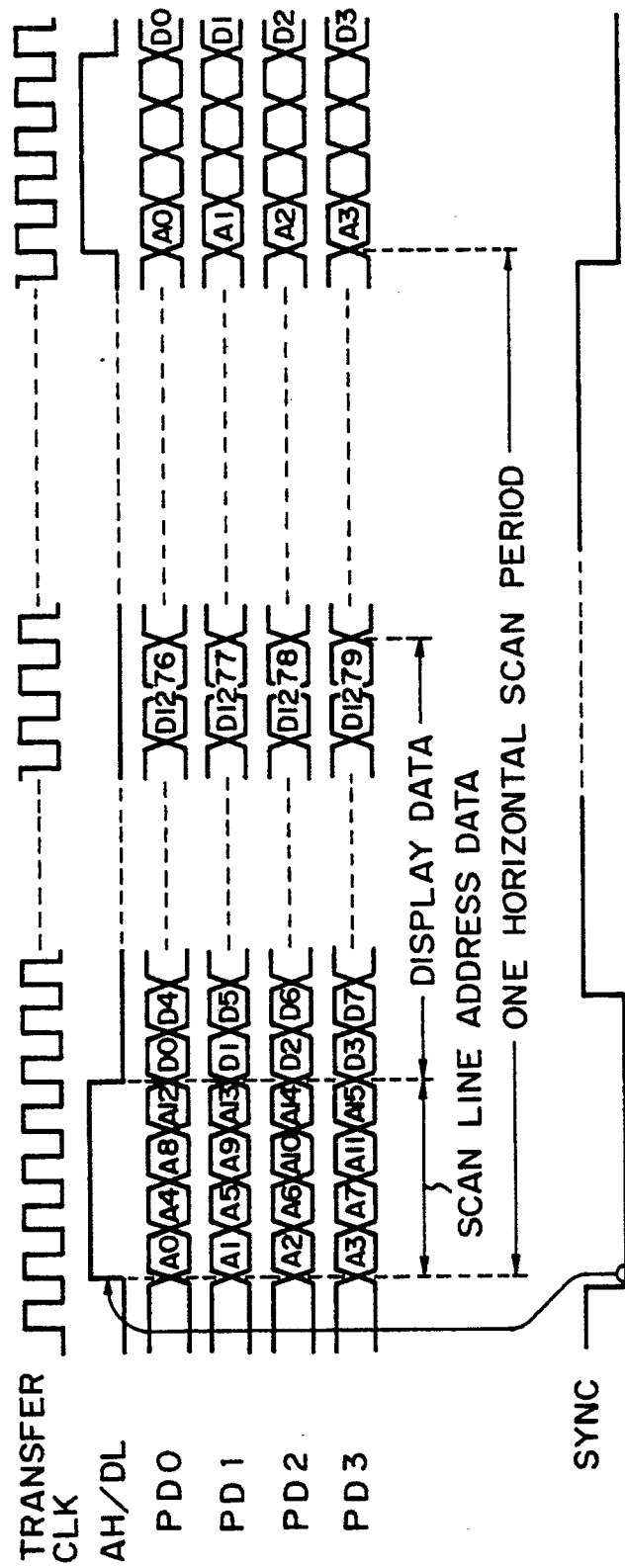


FIG. 7