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(54) **Method and apparatus for displaying gray-scale levels.**

(57) A liquid crystal matrix display has plural picture elements (PELs) arranged in an X-Y matrix. Each PEL includes a thin film transistor (TFT) and a display electrode. Data lines are formed in the X direction and gate lines in the Y direction. To display one of eight gray-scale levels for each PEL, one of eight voltage levels is selectively applied to the data line. The voltage levels are applied through a combination of switches which operate under the control of a selector which translates a three bit address into the selection of one or more switches. By this means the number of voltage sources and switches to operate a cell is less than the number of gray-scale values.

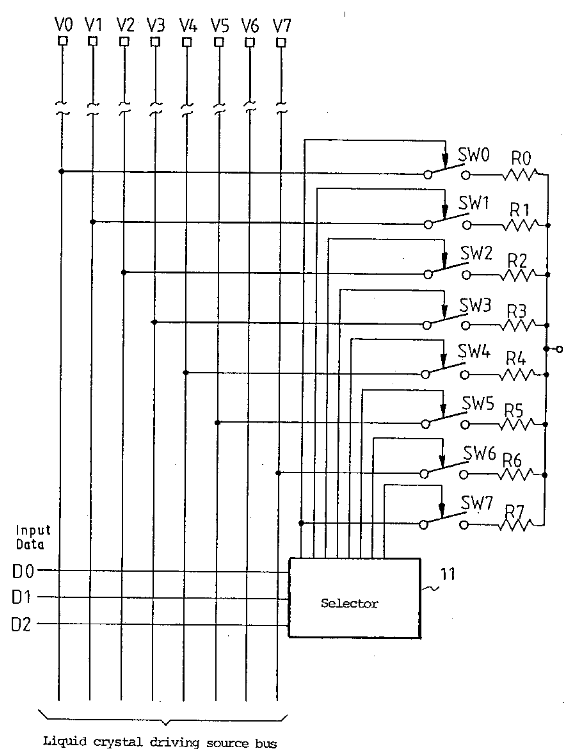

FIG. 4

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The present invention relates to improvements in an active matrix-type liquid crystal display (thereafter abbreviated LCD), more particularly to improvements for displaying multi gray-scale levels.

An active matrix LCD has scan bus lines and data bus lines which perpendicularly intersect each other and liquid crystal cells are connected, through switching elements such as thin-film transistors,to respective intersections of the scan bus lines and the data bus lines. Gray-scale levels are displayed by varying a data voltage under the on-off control of the switching elements.

In the conventional LCD described above, a data driver generates a drive voltage corresponding to digital data indicating a gray-scale level to be displayed. The drive voltage is selected by turning analog switches and needs more analog switches than gray-scale levels to be displayed. If the number of gray-scale levels (digital data) is N and polarity is reversed for each frame by analog switches, then 2^{N+1} analog switches are needed for each output. In this case, 2^{N+1} DC voltage sources, connected to the data driver, are needed as voltage sources for driving the liquid crystals. Also, if polarity is reversed for each frame by external voltage sources, 2^N analog switches are needed for each output. In this case, 2^N voltage sources for driving the liquid crystals, with the capability of reversing polarity for each frame, are needed. If data corresponding to the number of gray-scale levels is increased by one bit (the number of gray-scale levels is doubled), it is necessary to double analog switches and voltage sources for driving the liquid crystals in either case. For the above reasons, the prior art involves a problem that the cost of the apparatus is high.

An object of the present invention is to solve the above problem, that is, to provide an economical LCD by decreasing analog switches, voltage sources for driving liquid crystals, and the inputs of data driver which are needed to display gray-scale levels.

According to the present invention there is provided a method for operating a matrix display device having cells which display a range of gray-scale levels, plural voltage sources and plural switches for selecting said voltage sources to apply drive voltages to the cells in accordance with the gray-scale levels, the method comprising applying the drive voltages through switches which are selected by a selector which translates each gray-scale selection into a selection of one or a combination of the switches, each selection of one or more switches, presenting a drive voltage different from that presented by every other selection whereby the number of voltage sources and switches to operate a cell is less than the number of gray scale values for the cell.

Further according to the present invention there is provided a matrix display device having cells which display a range of gray-scale levels, plural voltage sources and plural switches for selecting said voltage sources to apply drive voltages to the cells in accordance with the gray-scale levels, the display device incorporating a selector to translate each gray-scale selection for a cell into a selection of one or a combination of the switches, each selection of one or more switches presenting a drive voltage different from that presented by every other selection of the switches whereby the number of voltage sources and switches to operate a cell is less than the number of gray-scale values for the cell.

FIG.1 shows a main circuit of the data driver of a display device according to the present invention. FIG.2 is a table showing the relationship between input data and voltages applied to the data line in the embodiment according to the present invention of Figure 1. FIG.3 shows the outline of the construction of a typical liquid crystal display panel. FIG.4 is a diagram showing a main circuit of the data driver constructed for conventional display of gray-scale levels.

In the drawings FIG.3 shows the outline of a conventional general active matrix LCD constructed so that an intermediate gray-scale level among multi gray-scale levels is displayed. Referring to FIG.3, voltage sources 2 for driving liquid crystal are connnected, through liquid crystal driving voltage source buses, to a data driver 1. The data driver 1 is connected to m data lines DL1 to DLm. A scan line driver 3 is connected to n scan lines GL1 to GLn. Each of the data lines DL1 to DLm is connected to respective source electrodes of n thin film transistors (thereafter abbreviated TFTs) 4. Each of the scan lines GL1 to GLn is connected to respective gate electrodes of m TFTs 4. Drainelectrode of each TFT 4 is connected to respective liquid crystal cell 5.

A liquid crystal panel 6 is comprised of m n TFTs 4 and the liquid crystal cells 5.

FIG.4 is a diagram showing a main circuit of the data driver shown in FIG.3. In the circuit, each of voltages corresponding to eight gray-scale levels can be applied to each data line. In the figure, liquid crystal driving source buses are connected to eight respective external voltage sources V0 to V7 for driving liquid crystals. Also, the liquid crystal driving source buses are connected to respective analog switches SW0 to SW7. The Switch On resistances of the analog switches SW0 to SW7 are R0 to R7, respectively. The respective ends of the switches (Switch On resistances R0 to R7 in the figure) are connected to a common line and a voltage outputted to the common line is applied to each data line DL. Three-bit input data D1 to D2 are inputted to a selector 11 connected, through eight selection lines, to the eight analog switches SW0 to SW7, respectively.

Now operations for displaying eight gray-scale levels are described by reference to FIG.3 and FIG.4.

First, the scan line driver 3 sequentially applies a pulse voltage to the scan lines GL1 to GLn. The TFT 4, when the pulse voltage is applied, will be turned on. Simultaneously, to the data lines DL1 to DLm, as shown in FIG.4, one of eight voltages obtained from selecting the analog switches and the source voltages for driving liquid crystals in the data driver in accordance with a predetermined gray-scale levels are applied to display one of eight gray-scale levels. For example, if the input data D0, D1, and D2 are 0, 1, and 0, respectively, in FIG.4, then the selector 11 turns the analog switch SW1 on, other analog switches SW0 and SW2 to SW7 remain turned off, and thus the voltage source V1 is selected and applied to one of the data lines. Also, if the input data D0, D1, and D2 are 1,0, and 1, respectively, then the selector 11 turns the analog switch SW5 on, other analog switches SW0 to SW4, SW6, and SW7 remain turned off, and thus the voltage source V5 is selected and applied to one of the data lines.

As described above, the source voltages to be applied to the data lines are varied to realize the display of gray-scale levels. Polarity of a source voltage applied to a data line is usually reversed for each frame.

FIG.1 shows a main circuit of a data driver of an embodiment according to the present invention. FIG.2 is a table showing the relationship between input data and a voltage applied to a data line. FIG.1 is the same as FIG.4 except that the number of voltage sources and the number of analog switches is decreased from eight to five.

Now, operations for displaying eight gray-scale levels are described by reference to FIG.1 to FIG.3.

In a case of the input data of, for example, D0 = 0, D1 = 1, and D2 = 1, a selector 11 turns on only one switch since D0 = 0. In this case, since D1 = 1 and D2 = 1, as is obvious from the table shown in FIG.2, the selector 11 turns on only an analog switch SW3 and a driving voltage V3 is applied, as shown in FIG.1(A), to a data line. Also, in a case of the input data of, for example, D0 = 1, D1 = 0 and D2 = 1, the selector 11 turns on two switches at a time since D0 = 1. In this case, since D1 = 0 and D2 = 1, the selector 11 turns on an analog switch SW2 and an analog switch SW3 of the following level simnltaneously and a driving voltage

$$\frac{R3\ V2 + R2\ V3}{R2 + R3}$$

is applied, as shown in FIG. 1(B), to the data line. The driving voltage is (V2 + V3)/2, which is an intermediate voltage between two driving voltage V2 and V3, if R0 = R1 = R2 = R3 = R4.

The relationship, which is obtained if data other than above example is inputted, between the states of the analog switches and the voltages applied to the data line is shown in FIG.2. The voltages thus obtained for each data line are applied to respective data lines DL1 to DLm shown in FIG.3. The TFTs 4 are sequentially scanned by the scan line driver 3 synchronously with the application of the voltages to the data lines to sequentially turn on the TFTs 4. To a data line of a liquid crystal 5 connected to a TFT 4 thus turned on, a voltage corresponding to a gray-scale level is applied, as described above, to display eight gray-scale levels.

As described above, if eight gray-scale levels are displayed according to the embodiment, the number of voltage sources and analog switches in the prior art are decreased from eight to five, that is, if K gray-scale levels are displayed, the number of voltage sources and analog switches decreased to K/2 + 1. Now, if the number of input data bits is represented by N, then $K = 2^N$ where K is an integer greater than or equal to 2.

In the present invention, by turning on two analog switches of a data driver simultaneously in response to the low-order bit of data to be displayed, liquid crystal driving voltages for displaying two different gray-scale levels are applied to a data line simultaneously to produce an intermediate voltage between the above voltages and display an intermediate gray-scale level between the two gray-scale levels.

In the present invention, by either turning on one switch or turning on at least two switches simultaneously in response to input data, one driving voltage level or at least two driving voltage levels are supplied to an output to display plural gray-scale levels far each pixel.

The present invention, as described above, has the advantage that by simultaneously applying driving voltages of two levels through two analog switches turned on simultaneously, the number of analog switches, driving sources, and inputs in the data driver are decreased to K/2 + 1, where K gray scales are required.

Claims

1. A method for operating a matrix display device having cells which display a range of gray-scale levels, plural voltage sources and plural switches for selecting said voltage sources to apply drive voltages to the cells in accordance

with the gray-scale levels, the method comprising applying the drive voltages through switches which are selected by a selector which translates each gray-scale selection into a selection of one or a combination of the switches, each selection of one or more switches, presenting a drive voltage different from that presented by every other selection whereby the number of voltage sources and switches to operate a cell is less than the number of gray scale values for the cell.

2. A matrix display device having cells which display a range of gray-scale levels, plural voltage sources and plural switches for selecting said voltage sources to apply drive voltages to the cells in accordance with the gray-scale levels, the display device incorporating a selector to translate each gray-scale selection for a cell into a selection of one or a combination of the switches, each selection of one or more switches presenting a drive voltage different from that presented by every other selection of the switches whereby the number of voltage sources and switches to operate a cell is less than the number of gray-scale values for the cell.

3. A device for displaying gray-scale levels according to claim (2), wherein the number of said plural gray-scale levels is K (where K is an integer greater than or equal to 2) and the number of said plural voltage is $K/2 + 1$.

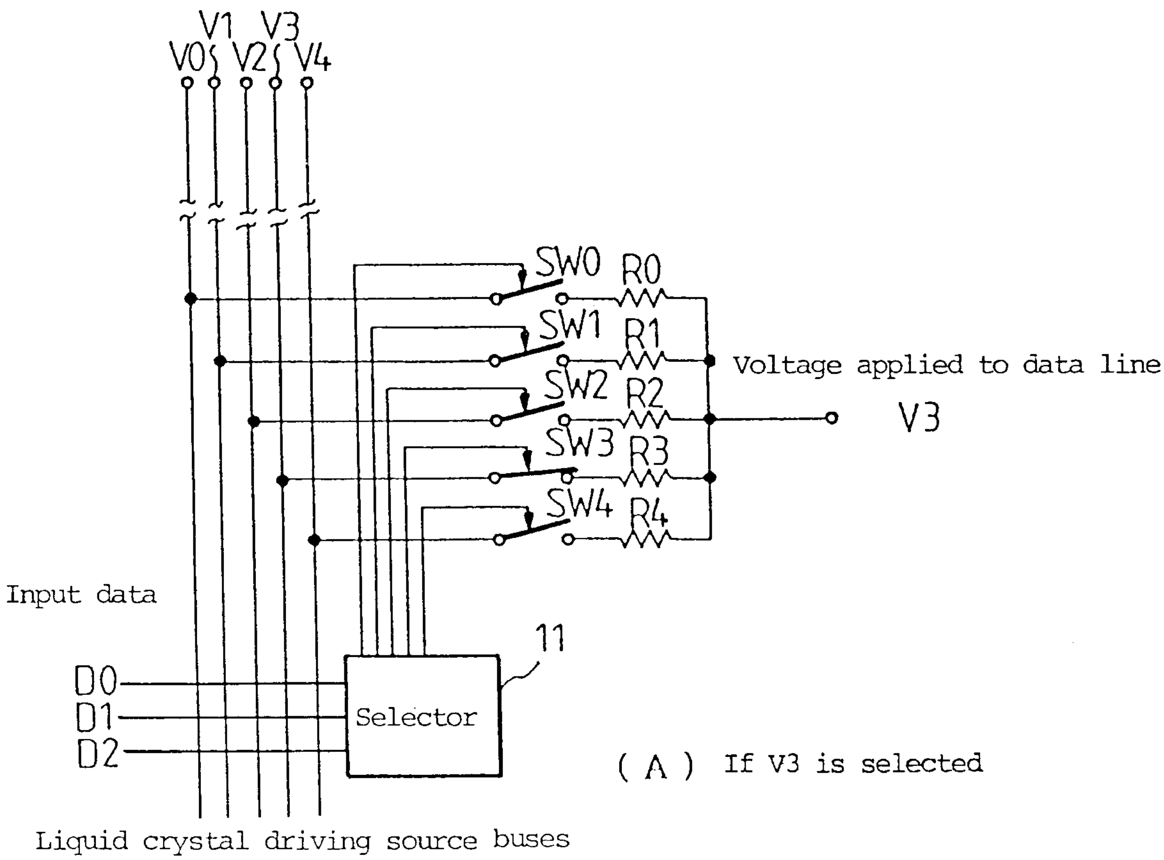
4. A device for displaying gray-scale levels according the claim (2) or (3) wherein the number of said plural switches is the same as the number of said voltage sources.

5. A device for displaying gray-scale levels according to claim (3) or (4) wherein said switches are analog switches.

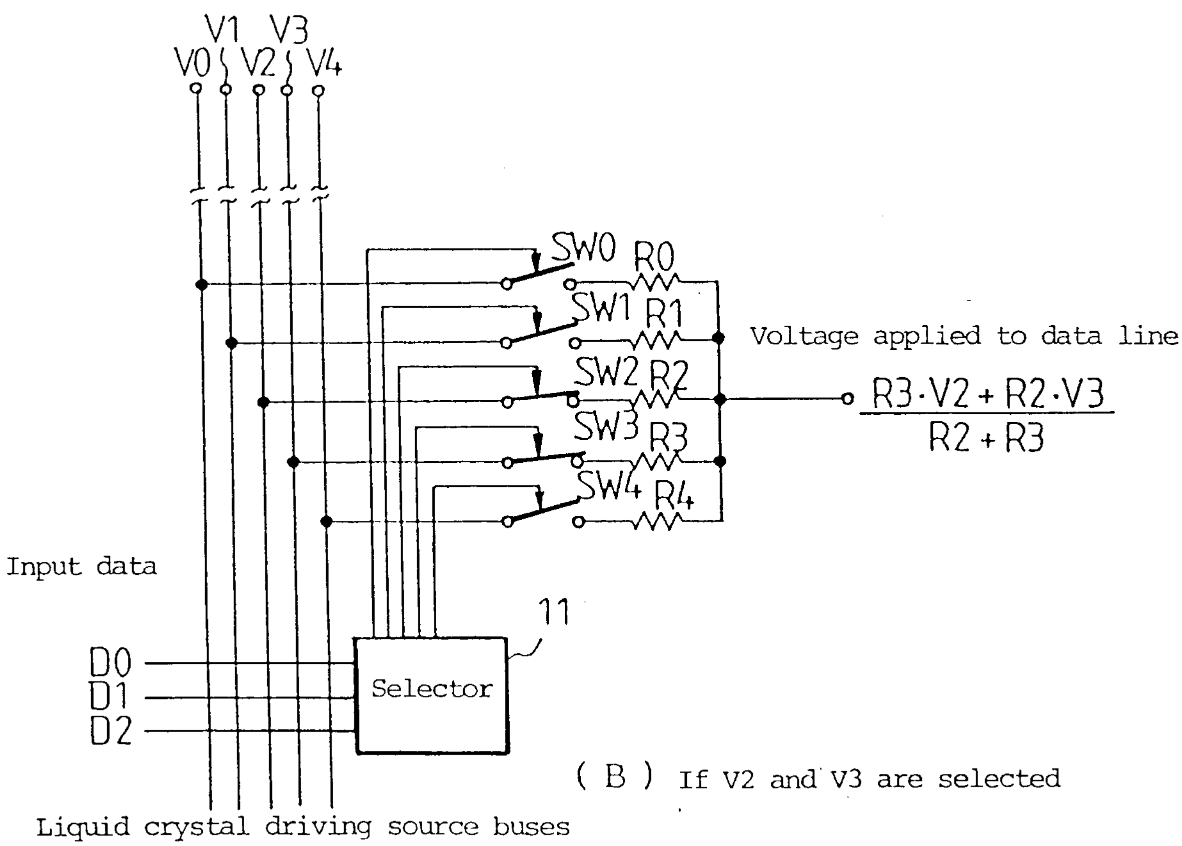
6. A device for displaying gray-scale levels according to claim (2), (3), (4) or (5) wherein each drive voltage is applied to a data line of each cell.

7. A device for displaying gray-scale levels according to any one of claims (2) to (6) wherein two switches can be selected to be turned on simultaneously, in accordance with a predetermined value of low-order bits of said input data.

8. A device for displaying gray-scale levels according to any one of claims (2) to (7) wherein said display device is a liquid crystal device.



(A) If V3 is selected



(B) If V2 and V3 are selected

FIG. 1

Input data			States of analog switches					Voltage applied to data line	
D2	D1	D0	SV0	SV1	SV2	SV3	SV4		if R0=R1=R2=R3=R4
0	0	0	ON	OFF	OFF	OFF	OFF	V0	V0
0	0	1	ON	ON	OFF	OFF	OFF	(R1·V0+R0·V1) ÷ (R0+R1)	(V0+V1) ÷ 2
0	1	0	OFF	ON	OFF	OFF	OFF	V1	V1
0	1	1	OFF	ON	ON	OFF	OFF	(R2·V1+R1·V2) ÷ (R1+R2)	(V1+V2) ÷ 2
1	0	0	OFF	OFF	ON	OFF	OFF	V2	V2
1	0	1	OFF	OFF	ON	ON	OFF	(R3·V2+R2·V3) ÷ (R2+R3)	(V2+V3) ÷ 2
1	1	0	OFF	OFF	OFF	ON	OFF	V3	V3
1	1	1	OFF	OFF	OFF	ON	ON	(R4·V3+R3·V4) ÷ (R3+R4)	(V3+V4) ÷ 2

FIG. 2

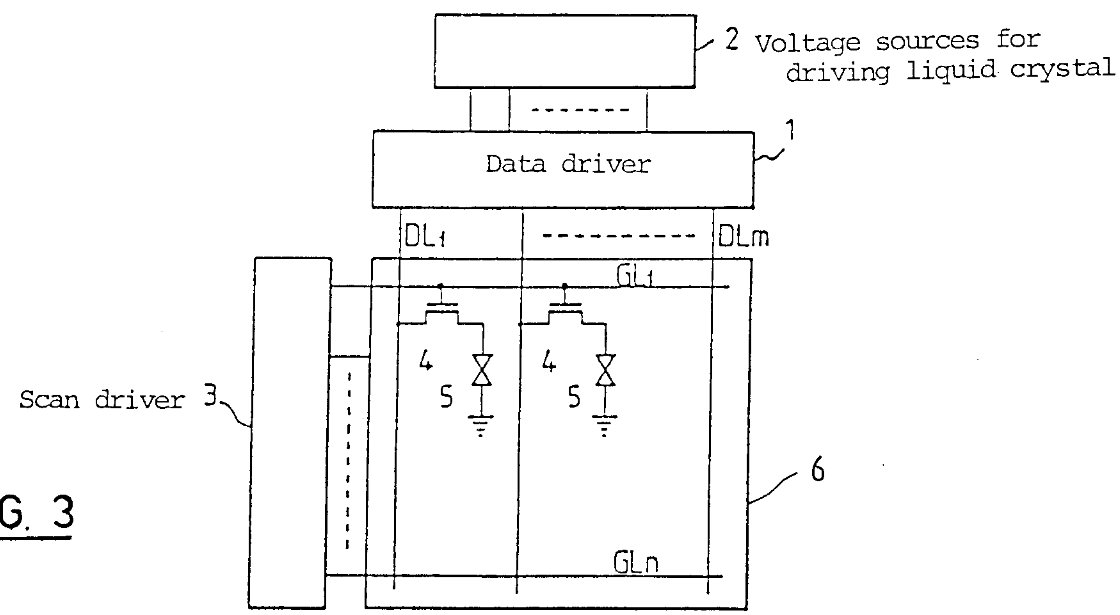


FIG. 3

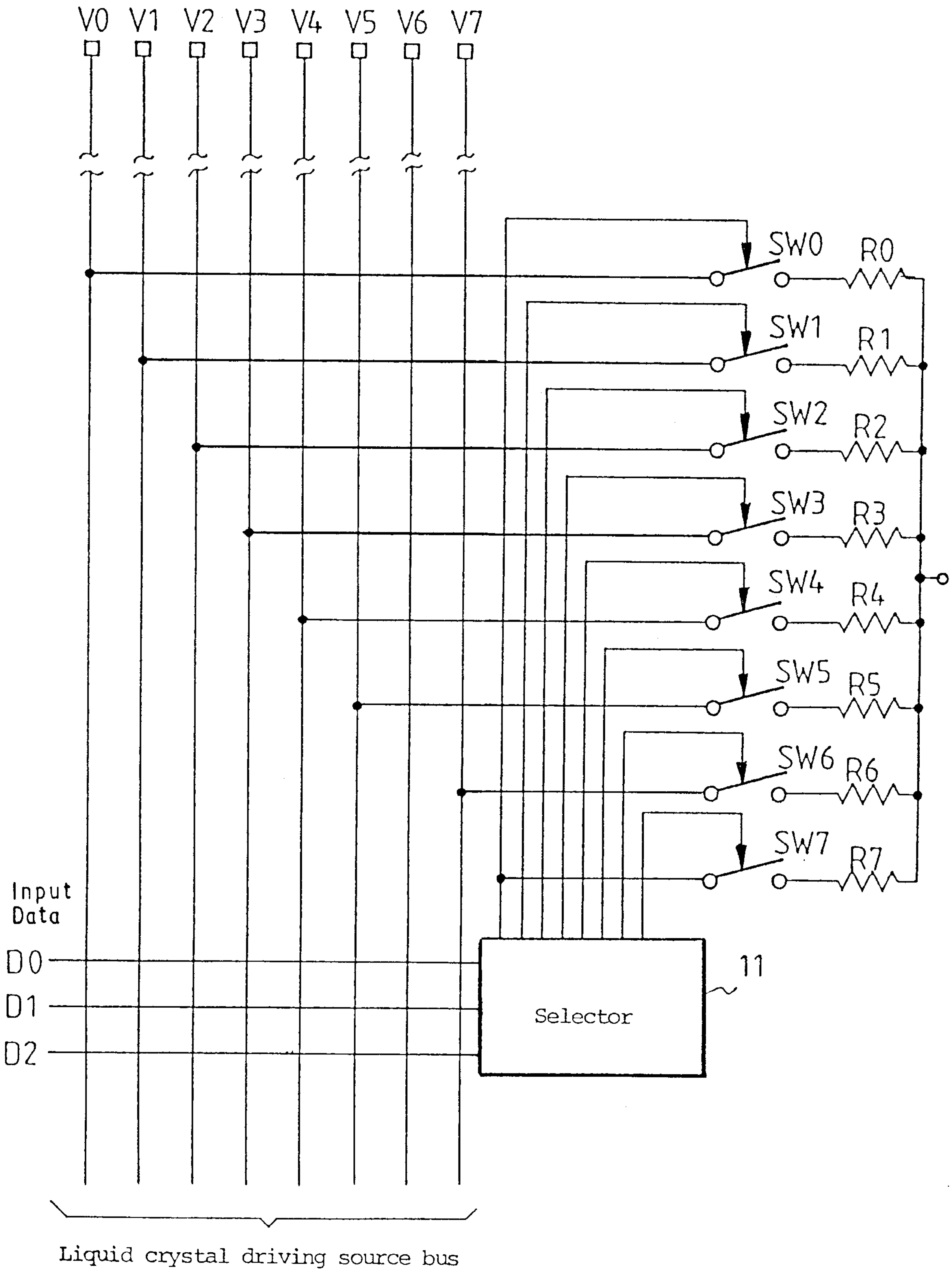

V0
V1
V2
V3
V4
V5
V6
V7
SW0
R0
SW1
R1
SW2
R2
SW3
R3
SW4
R4
SW5
R5
SW6
R6
SW7
R7
Input Data
D0
D1
D2
Selector
11
Liquid crystal driving source bus

FIG. 4