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(54) DRIVING CIRCUIT OF A LIQUID CRYSTAL DISPLAY AND RELATING DRIVING METHOD

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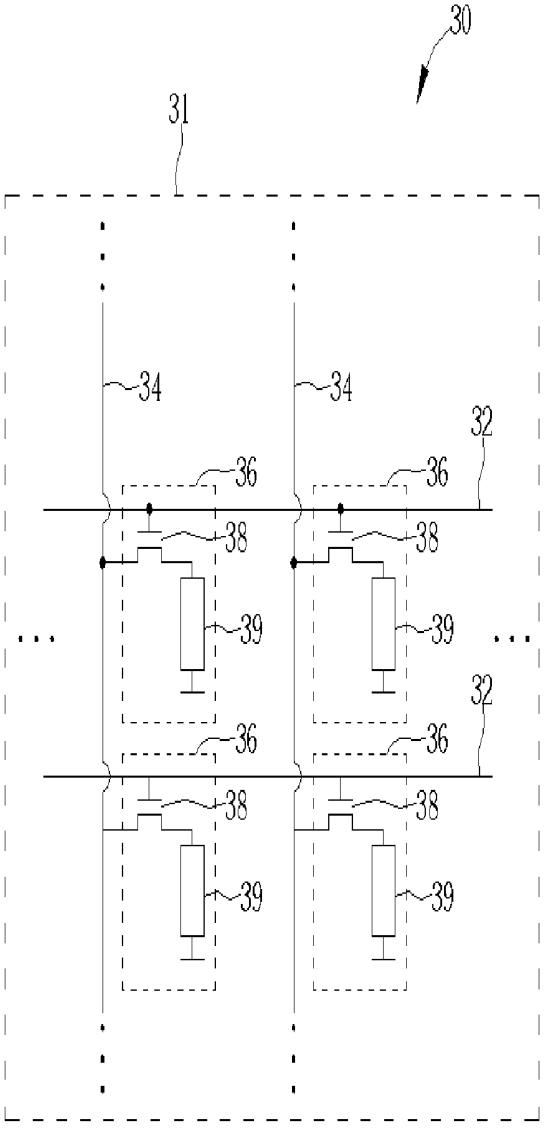
(57) **ABSTRACT**

A driving method of a liquid crystal display (LCD) includes (a) measuring reaction curves of LCD panel pixels switching from any gray scale value to others within a frame period and generating a standard table according to the results, (b) measuring adjustment gray scale values of any gray scale values for different gammas, (c) generating a plurality of tables according to the adjustment gray scale values and the standard table, (d) applying scan voltages to the scan lines, (e) receiving image data from an image signal terminal, (f) delaying the image data for a frame period to generate delayed image data, (g) selecting a table from the standard table and the tables according to gamma, and (h) selecting an image data value from the selected table according to the current and delayed image data to generate a data line voltage to be applied on a corresponding data line.



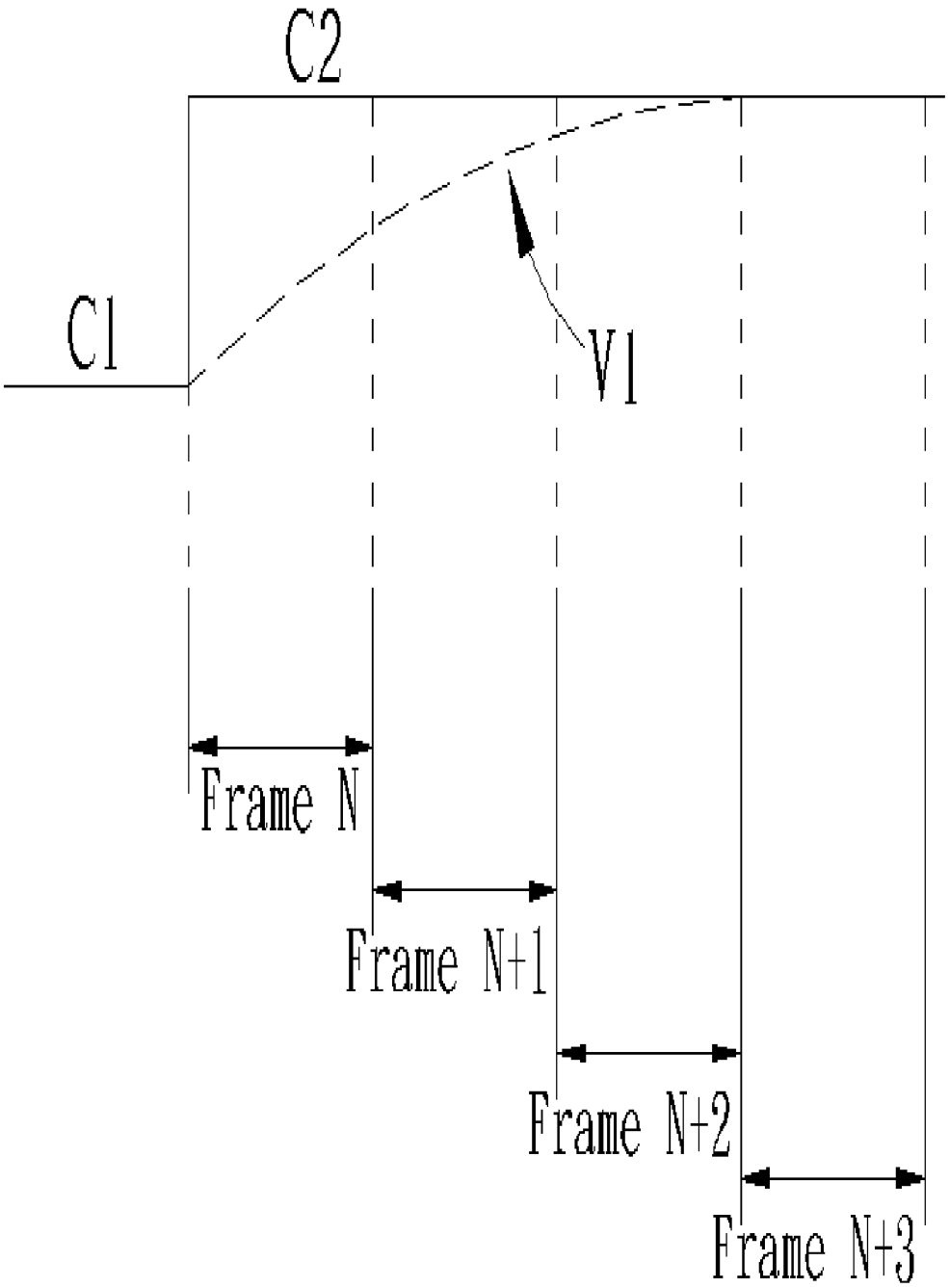


Fig. 1 Prior art

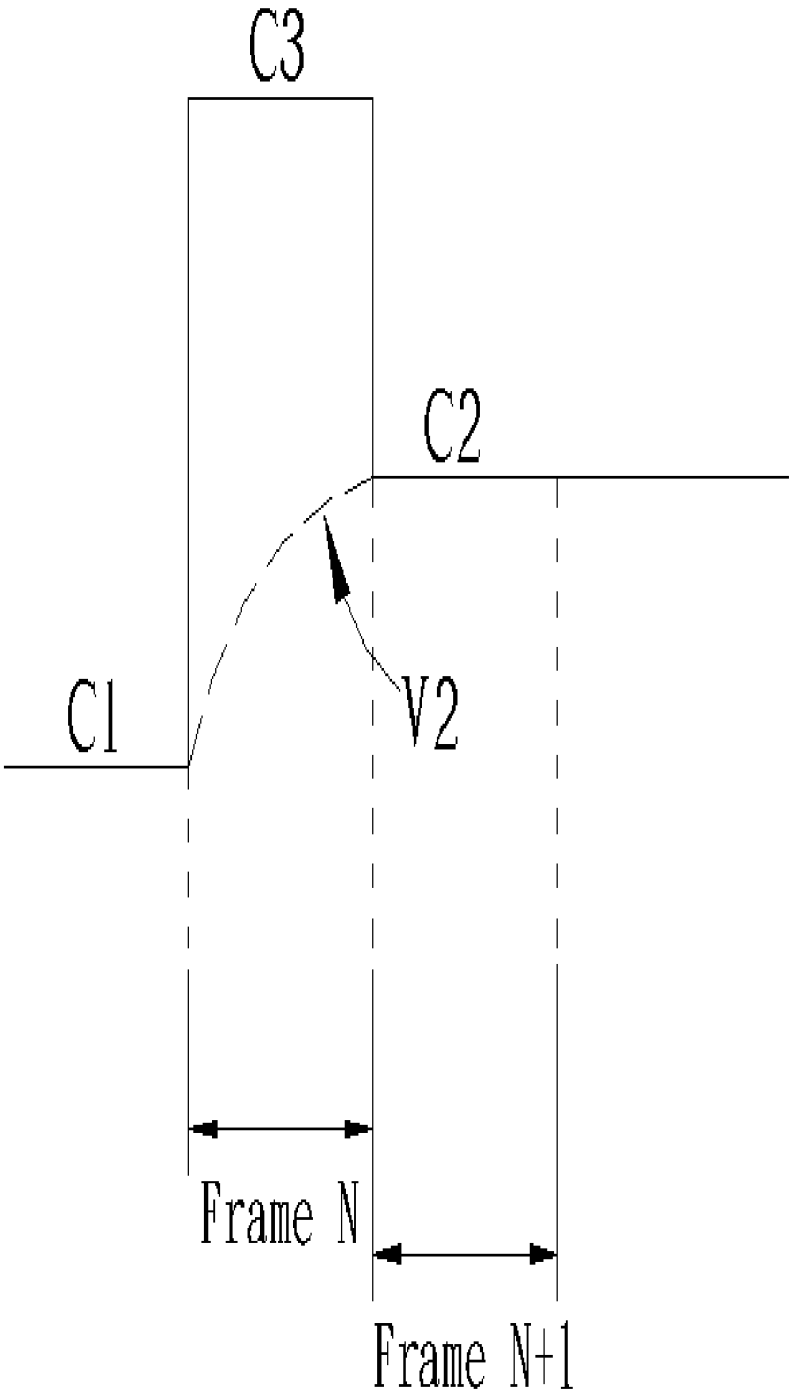


Fig. 2 Prior art

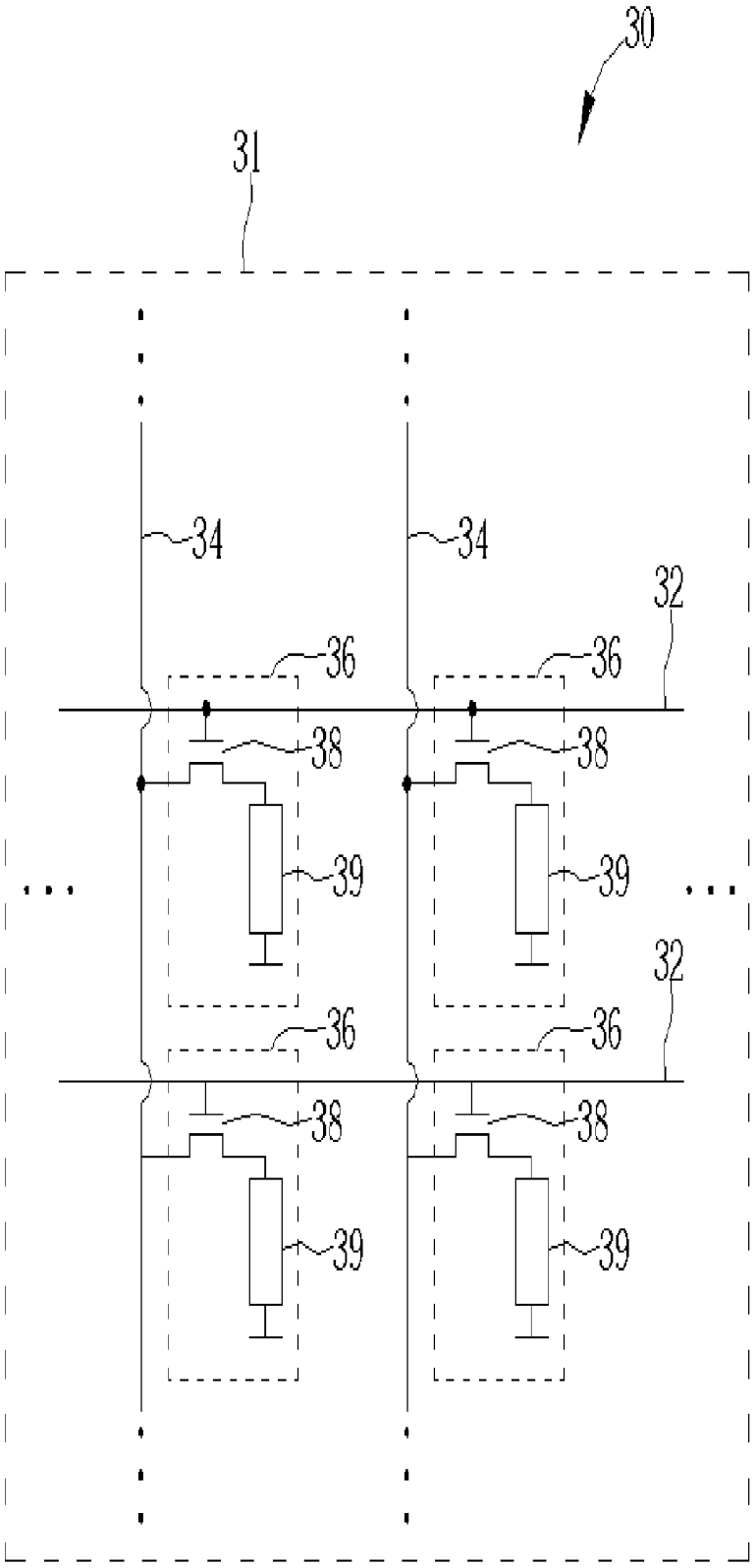


Fig. 3

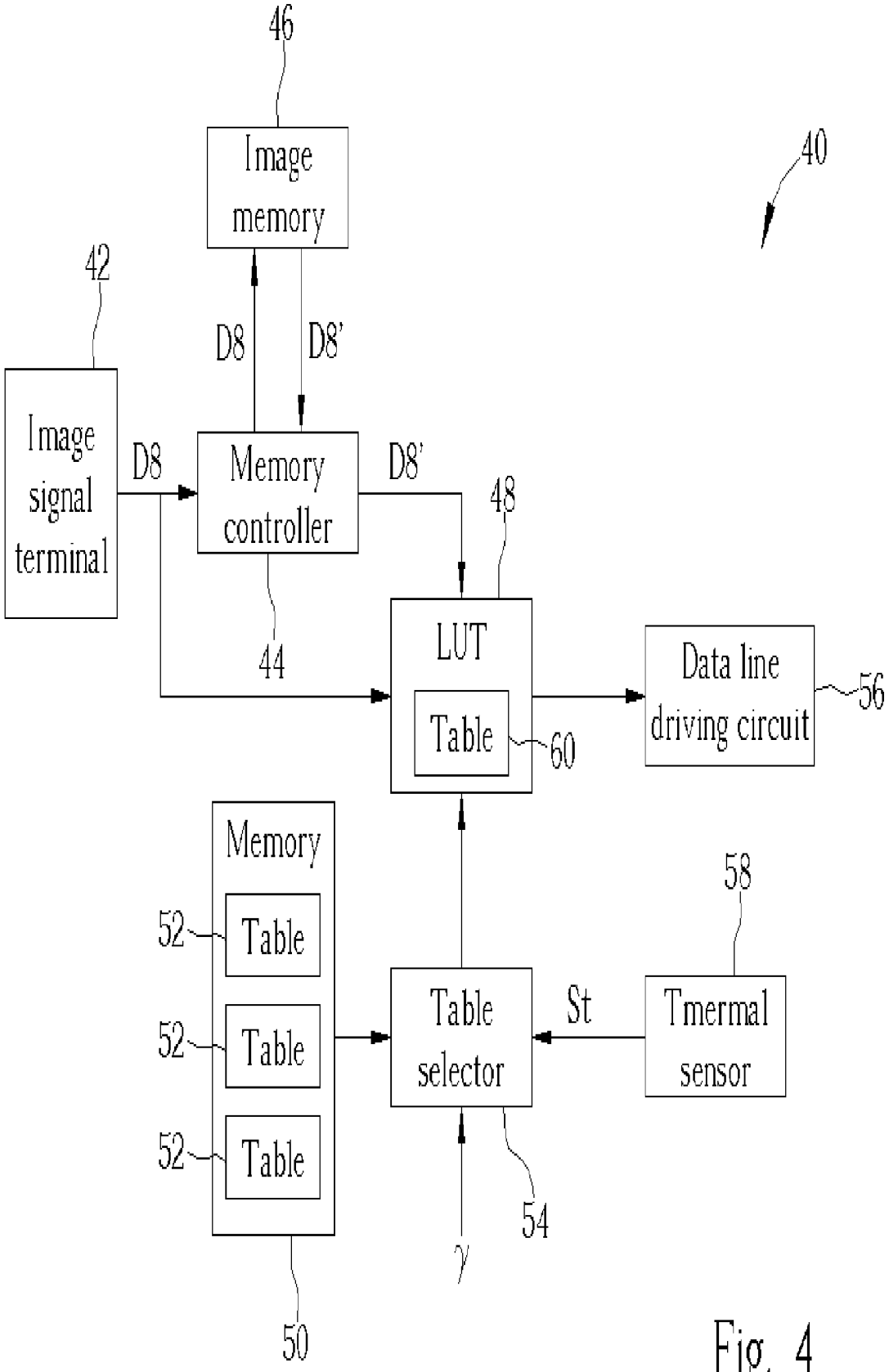

46
Image memory
40
42
D8
D8'
Image signal terminal
D8
Memory controller
D8'
48
44
LUT
Table
60
Data line driving circuit
56
Memory
52
Table
52
Table
52
Table
50
Table selector
St
Tmermal sensor
58
54
γ

Fig. 4

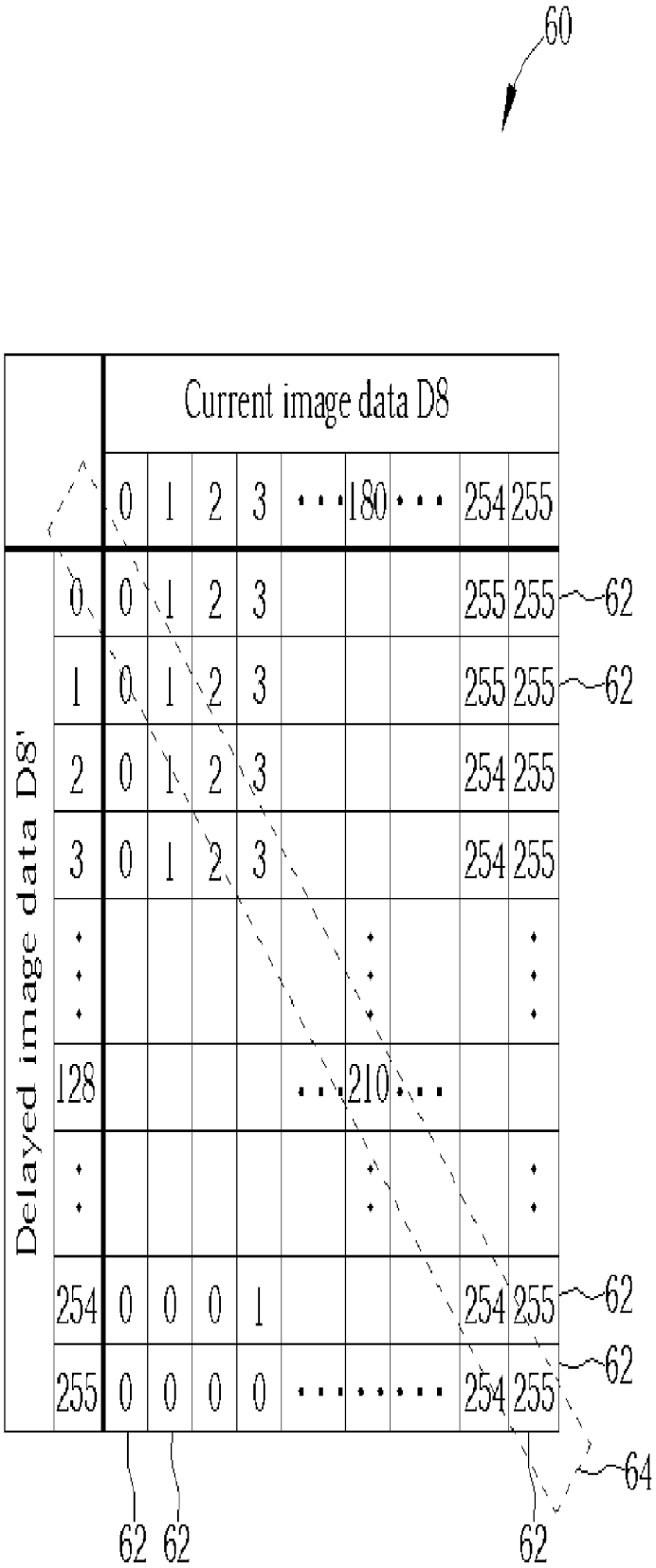

60
Current image data D8
0 1 2 3 ... 180 ... 254 255
Delayed image data D8'
0 0 1 2 3 255 255 62
1 0 1 2 3 255 255 62
2 0 1 2 3 254 255
3 0 1 2 3 254 255
128 ... 210 ...
254 0 0 0 1 254 255 62
255 0 0 0 0 ... ... 254 255 62
64
62 62 62

Fig. 5

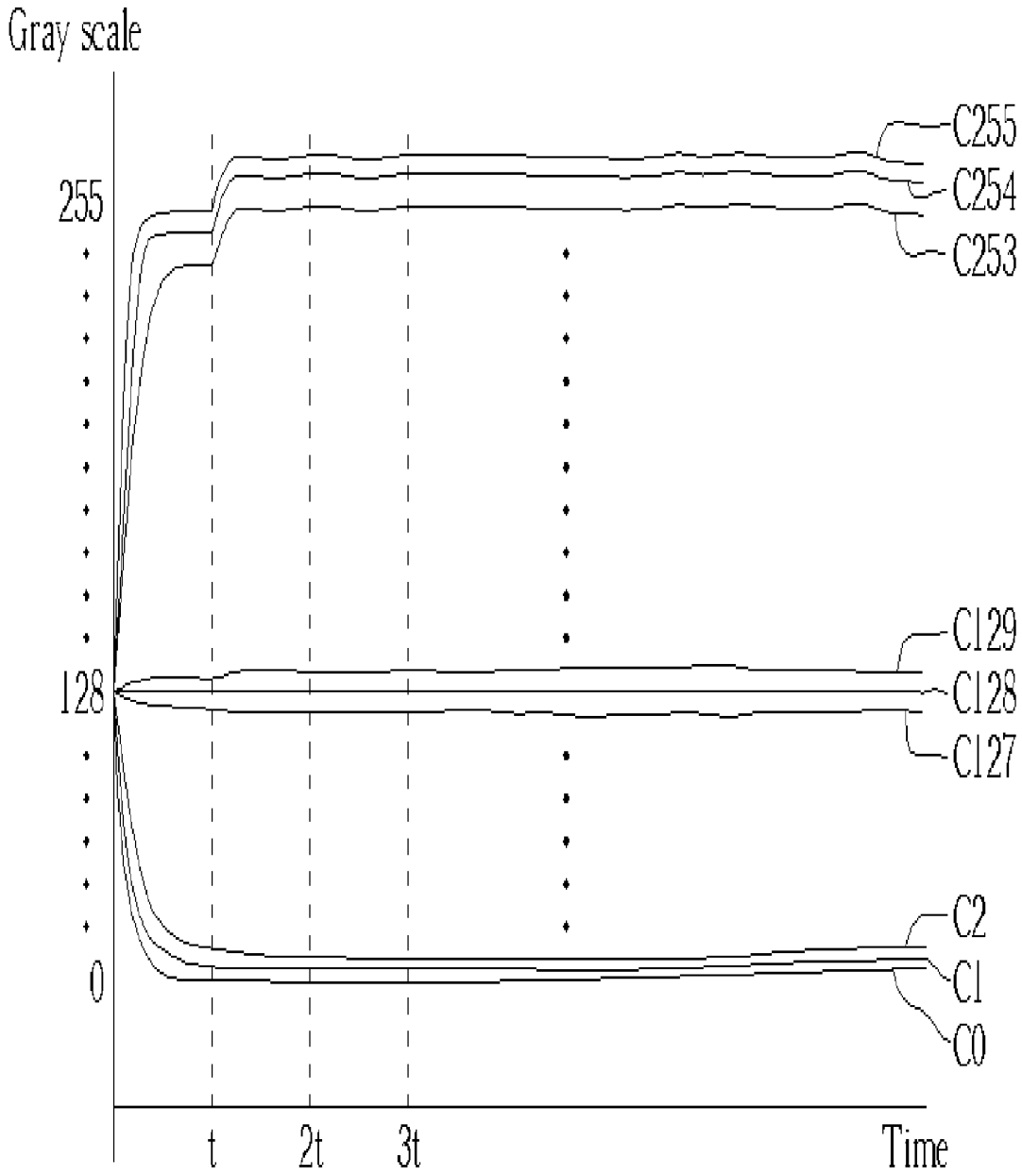

Gray scale
255
128
0
C255
C254
C253
C129
C128
C127
C2
C1
C0
t
2t
3t
Time

Fig. 6

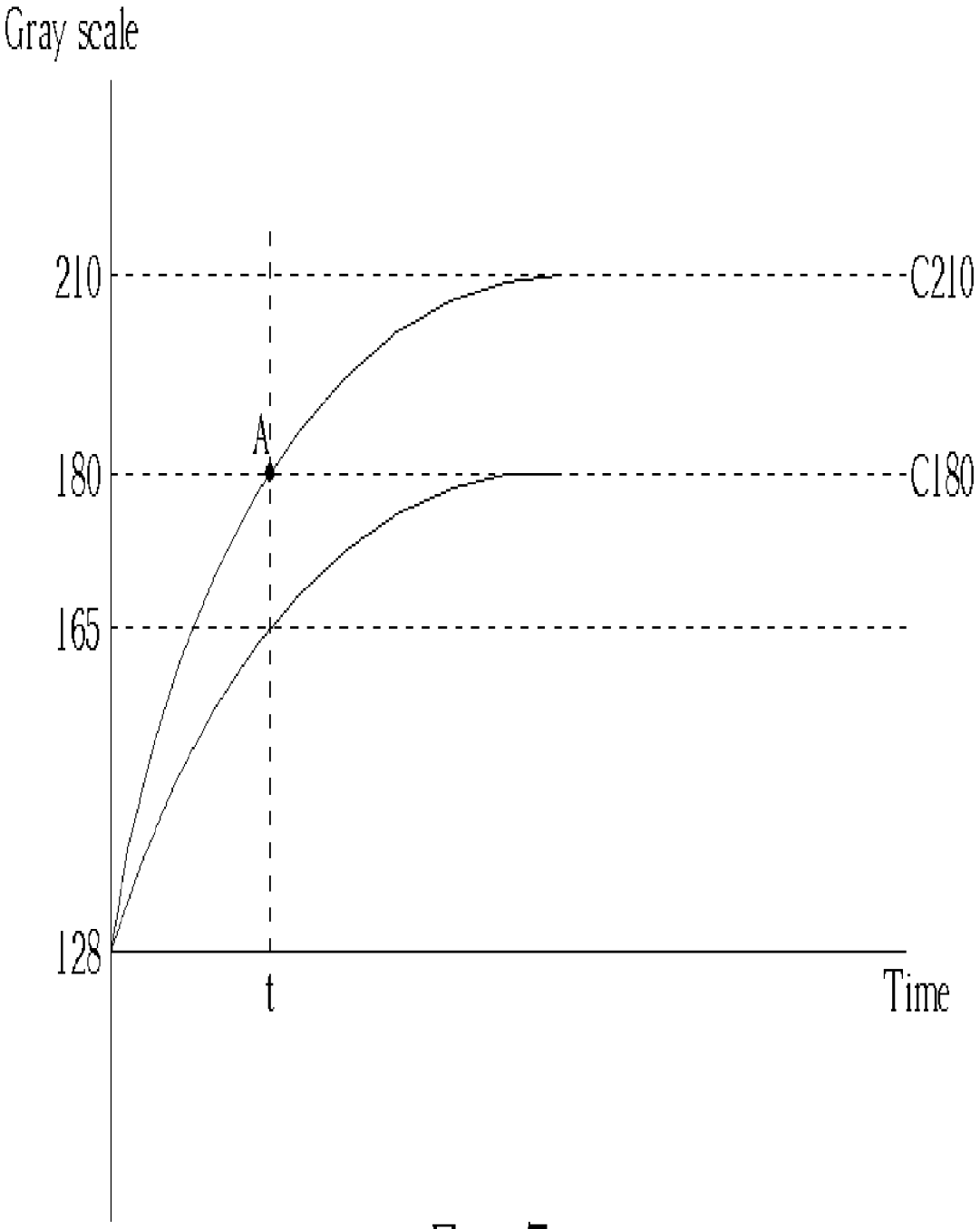


Fig. 7

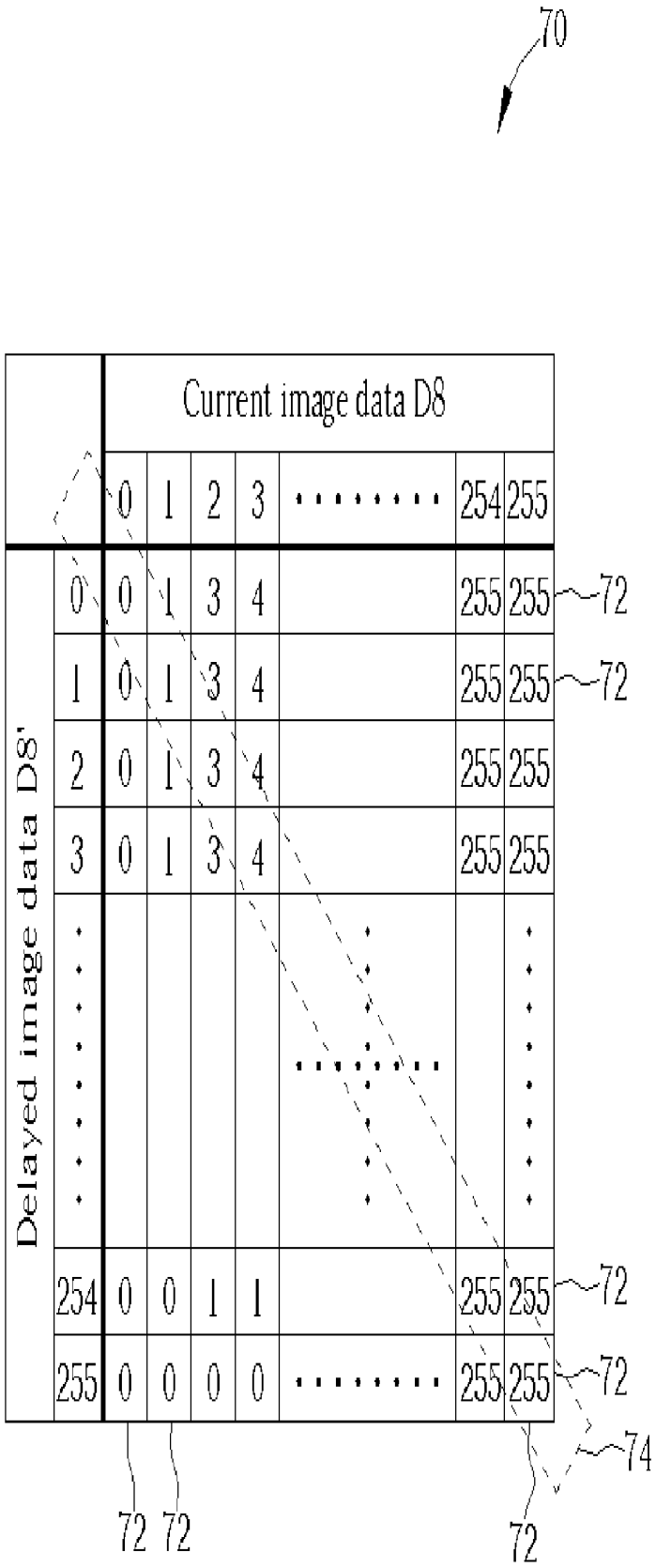

70
Current image data D8
Delayed image data D8'
0 1 2 3 ..... 254 255
0 0 1 3 4 255 255
1 0 1 3 4 255 255
2 0 1 3 4 255 255
3 0 1 3 4 255 255
254 0 0 1 1 255 255
255 0 0 0 0 ..... 255 255
72
74

Fig. 8

DRIVING CIRCUIT OF A LIQUID CRYSTAL DISPLAY AND RELATING DRIVING METHOD

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a driving circuit of a liquid crystal display and its relating driving method, and more particularly, to a driving circuit with its gamma adjustable and having a lookup table (LUT), and its relating driving method.

[0003] 2. Description of the Prior Art

[0004] A liquid crystal display (LCD) has advantages of lightweight, low power consumption, and low divergence and is applied to various portable equipment such as notebook computers and personal digital assistants (PDAs). In addition, LCD monitors and LCD televisions are gaining in popularity as a substitute for traditional cathode ray tube (CRT) monitors and televisions. However, an LCD does have some disadvantages. Because of the limitations of physical characteristics, the liquid crystal molecules need to be twisted and rearranged when changing input data, which can cause the images to be delayed. For satisfying the rapid switching requirements of multimedia equipment, improving the response speed of liquid crystal is desired.

[0005] Please refer to **FIG. 1**, which is a timing diagram of the pixel voltage and the transmission rate V1 according to a prior art LCD. In **FIG. 1**, the pixel voltage is shown with the straight lines, and the transmission rate V1 is shown with a dotted line. In **FIG. 1**, frame N means a frame period, and frame N+1, N+2 . . . mean the following frame periods. Due to the physical characteristics of liquid crystal molecules, when the pixel voltage is switched from a data voltage C1 to a data voltage C2, the liquid crystal molecules cannot be twisted to a predetermined angle within a single frame period, resulting in failure to perform at a predetermined transmission rate. As the curve of the transmission rate V1 shows, the transmission rate V1 cannot reach a predetermined transmission rate until the frame period of frame N+2. The delayed response-time will cause blurring on the LCD.

[0006] An over-driving method is utilized to improve the response-time. Please refer to **FIG. 2**, which is a timing diagram of the pixel voltage and the transmission rate V2 according to a prior art LCD using an over-driving method. When the pixel voltage is switched from the data voltage C1 to the data voltage C2, an over-driving data voltage C3 is added to accelerate the response speed of the liquid crystal molecules. Since a higher data voltage can obtain a faster response speed of the liquid crystal molecules, a data voltage C3 that is higher than the data voltage C2 can improve the response-time enough to reach the predetermined transmission rate in a single frame period. As **FIG. 2** shows, the curve of the transmission rate V2 reaches the predetermined transmission rate in frame N.

[0007] The U.S. published application No. 2002/0050965 discloses an over-driving method using a brief table to store the over-driving image data. The brief table only includes part of the over-driving image data for driving the pixels switched from one gray scale to another. When the driving circuit receives the image data from the input terminal, a processor is used to perform an interpolation operation to expand the brief table. Hence, an extra algorithm is needed in the conventional over-driving method. The effect of using an extra algorithm is that it will slow down the response speed.

[0008] In addition, there is no description relating to the adjustment of gamma of an LCD. In the prior art, the overdrive and adjustment of gamma depend respectively on two different circuits, which complicates the whole circuit.

SUMMARY OF INVENTION

[0009] It is therefore a primary objective of the claimed invention to provide a driving circuit with an adjustable gamma and an LUT of an LCD along with the relating driving method to solve the problem mentioned above.

[0010] Briefly, the present invention provides a driving method of an LCD. The LCD includes an LCD panel; the LCD panel includes a plurality of scan lines, a plurality of data lines, and a plurality of pixels. Each pixel is connected to a corresponding scan line and a corresponding data line, and each pixel comprises a switching device connected to the corresponding scan line and the corresponding data line. The method includes (a) measuring reaction curves of a pixel of the LCD panel switched from any gray scale values to other gray scale values within a frame period and generating a standard table according to the reaction curves measured, (b) measuring adjustment gray scale values of any gray scale values for different gammas, (c) generating a plurality of tables according to the adjustment gray scale values and the standard table, (d) applying scan voltages to the scan lines, (e) receiving image data from an image signal terminal, (f) delaying the image data for a frame period in order to generate delayed image data, (g) selecting a table from the standard table and the tables according to the gamma, and (h) selecting an image data value from the selected table according to the current image data and the delayed image data and generating a data line voltage according to the image data value, applying the generated data line voltage on a corresponding data line.

[0011] The present invention further provides a driving circuit for driving an LCD. The driving circuit includes a scan line driving circuit for applying scan voltages to the scan lines, an image signal terminal for receiving image data, an image memory for storing the image data and delaying the image data for a frame period, a memory for storing the plurality of tables, a selector for selecting a table from the plurality of tables according to the gamma, a look up table for selecting an image data value from the selected table according to the current image data and the delayed image data, and a data line driving circuit for generating a data voltage according to the image data value, applying the generated data voltage to a corresponding data line.

[0012] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0013] **FIG. 1** is a timing diagram of pixel voltage and transmission rate according to prior art.

[0014] **FIG. 2** is a timing diagram of pixel voltage and transmission rate according to prior art using an over-driving method.

[0015] **FIG. 3** is a circuit diagram of a typical LCD.

[0016] **FIG. 4** is a block diagram of a driving circuit according to the present invention.

[0017] **FIG. 5** illustrates a table used by the LUT in **FIG. 4**.

[0018] **FIG. 6** illustrates the measured reaction curves of the LCD panel.

[0019] **FIG. 7** illustrates the method to determine overdrive image data in the table.

[0020] **FIG. 8** illustrates a table in **FIG. 5** whose gamma is adjusted.

DETAILED DESCRIPTION

[0021] Hereby the operation of an LCD is described in advance. Please refer to **FIG. 3**, which is a circuit diagram of a typical LCD **30**. The LCD **30** comprises an LCD panel **31**, and the LCD panel **31** includes a plurality of scan lines **32**, a plurality of data lines **34**, and a plurality of pixels **36**. Each pixel **36** is connected to a corresponding scan line **32** and a corresponding data line **34**, and each pixel **36** has a switching device **38** and a pixel electrode **39**. The switching device **38** is connected to the corresponding scan line **32** and the corresponding data line **34**. To drive the LCD **30**, scan voltages are applied to the scan lines **32** to turn on the switching devices **38**, and data voltages are applied to the data lines **34** and transmitted to the pixel electrodes **30** through the switching devices **38**. Therefore, when the scan voltages are applied to the scan lines **32** to turn on the switching devices **38**, the data voltages on the data lines **34** will charge the pixel electrodes **39** through the switch devices **38** thereby, twisting the liquid crystal molecules. When the scan voltages on the scan lines **32** are removed to turn off the switching devices **38**, the data lines **34** and the pixels **36** will disconnect, and the pixel electrodes **39** will remain charged. The scan lines **32** turn the switching devices **38** on and off repeatedly so that the pixel electrodes **39** can be repeatedly charged. Different data voltages cause different twisting angles and show different transmission rates. Hence, the LCD **30** displays various images.

[0022] Please refer to **FIG. 4**, which is a block diagram of a driving circuit according to the present invention. The driving circuit **40** is for driving the LCD **30** in **FIG. 3**. The driving circuit **40** includes an image signal terminal **42**, a memory controller **44**, an image memory **46**, an LUT **48**, a memory **50**, a table selector **54**, a data line driving circuit **56**, and a thermal sensor **58**. In the present embodiment, the image signal terminal **42** respectively transmits 8-bit image data of red, greed and blue (RGB) to the memory controller **44** and the LUT **48**. Each group of image data is for controlling the gray scale value of the pixel **30** in red, green or blue. Each color has 256 (2^8) gray scales, so that 24 (8*3) bits of image data are required to determine the properties of each pixel **30**.

[0023] In the present embodiment, one (image data D8) of the 3 groups of image data is used for a further description. First, the image signal terminal **42** transmits the 8-bit image data D8 to the memory controller **44** and the LUT **48**. Continuously, the memory controller **44** transmits the image data D8 to the image memory **46** to store, delays the image data D8 for a frame period, and then reads the image data D8 out from the image memory **46** and transmits them to the LUT **48**. The image data D8 delayed for a frame period is hereby defined as delayed image data D8. Therefore, the delayed image data D8 and the image data D8 belong to two different frames, and these two image data D8" and D8 are input from the image signal terminal **42** in sequence at an interval of a frame period.

[0024] The memory **50** stores a plurality of parameter tables **52**. Each table **52** corresponds to different gammas. The driving circuit **40** can select the proper table **52** to use as the LUT **48** to drive the LCD panel **31** according to the gamma. For this reason, a table selector **54** is used to select a table **60** from the plurality of tables **52** according to the gamma and send it to the LUT **48**.

[0025] Please refer to **FIG. 5** showing a table **60** used by the LUT **48** in **FIG. 4**. The table **60** stores (2^8×2^8) pieces of 8-bit overdrive image data **62**. Each piece of image data **62** corresponds to different combinations of the current image data D8 and the delayed image data D8. The LUT **48** selects an image data value **62** from the table **60**, selected by the table selector **54**, according to the current image data D8 and the delayed image data D8 and then sends it to the data line driving circuit **56**. Continuously, the data line driving circuit **56** generates a data line voltage according to the image data value **62** output from the LUT **48** and applies it to a corresponding data line **34**. Take for instance the situation where the delayed image data D8 is 128 and the current image data D8 is 180, i.e. the corresponding pixel **36** is switched from gray scale 128 to gray scale 180. In this case the LUT **48** selects the image data value **62** with a value of 210 from the table **60** according to the current image data D8 and the delayed image data D8. In response, the data line driving circuit **56** generates a data line voltage corresponding to the image data value **62** with a value of 210 and applies it to the corresponding data line **34**. In addition, please notice that the selected image data value **62** is larger than the value of the current image data D8 (i.e. 210>180), which means the driving circuit **40** overdrives the pixel **36**.

[0026] Additionally, in contrast to the prior art, which uses a processor to extract values in a table by interpolation, the image data values in the tables **52** according to the present invention are previously stored in the memory **50**. Therefore, the driving circuit **40** according to the present invention does not require the processor for extraction as in the prior art. The image data values in the tables **52** are obtained by measuring the LCD panel **31** so that the driving circuit **40** can overdrive the LCD panel **31** correctly without an operation such as interpolation as in the prior art. Please refer to **FIG. 6** showing the measurement of reaction curves of the LCD panel **31**. Before determining the overdrive image data in the table **52**, reaction curves representing a pixel **36** switching from any gray scale value to other gray scale values in a frame period t can be measured. **FIG. 6** shows the reaction curves C**0**~C**255** representing the pixel **36** switching from a gray scale value 128 to any other gray scale values (0~255). In the case of measuring the LCD panel **31** used in the above examples, since the pixel **36** is switched among 256 gray scales, there are 256 reaction curve diagrams like **FIG. 6** shown respectively for the pixel **36** switching from one gray scale value (0~225) to other gray scale values within a frame period t.

[0027] Please refer to **FIG. 7** showing the method used to determine overdrive image data in the table **52**. Take a pixel

36 switched from gray scale value 128 to gray scale value 180 for an example. As shown in **FIG. 7**, if the pixel electrode **39** of the pixel **36** is subject to a data voltage corresponding to gray scale 180, the gray scale is not able to reach 180 in a frame period t. Thus, an overdrive voltage is required to be applied to the pixel electrode **39** of the pixel **36**. Therefore, the data voltage required to have the pixel electrode **39** of the pixel **36** switch from the gray scale value 128 to 180 in a frame period can be known by using the reaction curves C**0**~C**225** in **FIG. 6**. The method to determine overdrive image data is as follows:

[**0028**] (1) Find an intersection A (as shown in **FIG. 7**) between a vertical line of frame period t and a horizontal line of the gray scale value 180 in **FIG. 6**; and

[**0029**] (2) Determine which one of the reaction curves C**0**~C**225** is closer to A. Image data (or gray scale value) corresponding to the reaction curve closer to A is the required overdrive image data.

[**0030**] In the said example, since the reaction curve corresponding to image data 210 passes A, the required overdrive image data for the pixel **36** switched from gray scale value 128 to 180 is 210. Moreover, each table **50** stores $(2^8 \times 2^8)$ 8-bit overdrive image data, and each piece of the image data is obtained by measuring the LCD panel **31**. In addition, please notice that during the gray scale switching of the pixel **36**, if the difference between two neighboring gray scales is too large (e.g. 128 to 255) so that the switching cannot be completed in a frame period t, the overdrive data value will be 0 or 255, wherein 0 is for a high gray scale value to a low gray scale value, and 255 is for a low gray scale value to a high gray scale value.

[**0031**] In addition, the table **60** in **FIG. 5** obtained by measurement is defined as a standard table. The overdrive image data **62** in the column along a diagonal line **64** from the upper-left to the lower-right equals to the corresponding delayed image data D**8** and the corresponding image data D**8**. That means the gamma of the table **60** has not been adjusted, i.e. the gamma corresponding to the table **60** is **1**. Compared with the table **60** in **FIG. 6**, **FIG. 8** shows a table **70** whose gamma has been adjusted. Being the same as the standard table **60**, the table **70** is selected from the plurality of tables **52** in the memory **50**, and it stores a plurality of overdrive image data **72** for the LUT **48**. The difference is that in the table **70**, the gamma is adjusted so that all the overdrive image data **72** in the columns along the diagonal line **74** do not necessarily equal to the corresponding delayed image data D**8** and the corresponding image data D**8**. Moreover, the overdrive image data **72** in the table **70** is relative to the overdrive image data **62** in the table **60** because the overdrive image data **72** is obtained through the following steps:

[**0032**] (1) Measure an adjustment gray scale value of every gray scale value of the pixel **36** for a specific gamma. Take the table **70** for example. Now measure all the overdrive image data **72** in the columns along the diagonal line **74**; and

[**0033**] (2) Solve other overdrive image data **72** to fill in the rest of the table (i.e. the spaces not along the diagonal) by using the adjustment gray scale value and the standard table **60**. To solve for an image data value **72** on the table **70**, find the diagonal image data **72** located on the same row i.e. D**8** as the image data **72** that needs to be solved. Replace the D**8** coordinate with the diagonal image data **72** value and look up the value using the new coordinates on the standard table **60**. The image data value **62** located at the new coordinates is the value of the image data **72** to be solved. Take the overdrive image data **72** located at (D**8**, D**8**)=(2, 1) in the table **70** for example. The overdrive image data **72** in the column along the diagonal line **74** and on the same line as (2,1) has an the image data value of 3. Replacing the old D**8** coordinate (2) with the image data value of 3, the new coordinates become (3,1) after adjustment. Using the new coordinates on table **60**, it is found that the image data **62** has a value of 1. By this way, it can be known that the overdrive image data **72** (D**8**, D**8**)=(2, 1) in the table **70** is equal to the overdrive image data **62** (D**8**, D**8**)=(3, 1) in the table **60**, the overdrive image data being equal to 1.

[**0034**] Moreover, tables **50** corresponding to other gammas can be generated according to the method mentioned above. Measure overdrive image data in columns along a diagonal line of each table **50**, and then solve other overdrive image data according to the standard table **60** and the overdrive data in the columns along the diagonal line.

[**0035**] Additionally, when the liquid crystal molecules are twisted according to data voltage change, the response time of the twisting differs according to the temperature of the LCD panel **31**. For better performance under various temperature, the driving circuit **40** selects the table according to the temperature of the LCD panel **31** by generates temperature compensation signals St sending them to the table selector **54** so that the table selector **54** selects a table from the plurality of tables **52** stored in the memory **50**, according to both gamma and the temperature compensation signals St, and transmits the selected table to the LUT **48**.

[**0036**] In contrast to the prior art, the tables according to the present invention are built by actually measuring the over-driving voltages needed for properly driving the liquid crystal panel within a frame period. The tables include all the over-driving image data that drives the pixels from any gray scale to another so that the processor used to extract the brief table is no longer required. Additionally, the driving circuit and the driving method of the present invention is capable of selecting different tables according to gamma and temperature of the LCD panel for the LUT.

[**0037**] Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

1. A driving method of a liquid crystal display (LCD), the LCD comprising:

an LCD panel, the LCD panel comprising:

a plurality of scan lines;

a plurality of data lines; and

a plurality of pixels, each pixel being connected to a corresponding scan line and a corresponding data line,

and each pixel comprising a switching device connected to the corresponding scan line and the corresponding data line; and

the method comprising:

(a) measuring reaction curves of the pixels of the LCD panel switched from any gray scale value to other gray scale values in a frame period, and generating a standard table according to the reaction curves measured;

(b) measuring adjustment gray scale values of any gray scale value for different gammas;

(c) generating a plurality of tables according to the adjustment gray scale values and the standard table;

(d) applying scan voltages to the scan lines;

(e) receiving image data from an image signal terminal;

(f) delaying the image data for a frame period in order to generate delayed image data;

(g) selecting a table from the standard table and the tables according to gamma; and

(h) selecting an image data value from the selected table according to the current image data and the delayed image data and generating a data line voltage according to the image data value, applying the generated data line voltage on a corresponding data line.

2. The method of claim 1 further comprising:

(i) generating temperature compensation signals according to temperature of the LCD panel; and

(j) selecting the table from the standard table and the tables according to the gamma and the temperature compensation signals in step (g).

3. A driving method of a liquid crystal display (LCD), the LCD comprising:

an LCD panel, the LCD panel comprising:

a plurality of scan lines;

a plurality of data lines; and

a plurality of pixels, each pixel being connected to a corresponding scan line and a corresponding data line, and each pixel comprising a switching device connected to the corresponding scan line and the corresponding data line;

the method comprising:

(a) applying scan voltages to the scan lines;

(b) receiving image data from an image signal terminal;

(c) delaying the image data for a frame period in order to generate delayed image data;

(d) selecting a table from the standard table and the tables according to gamma; and

(e) selecting an image data value from the selected table according to the current image data and the delayed image data, and generating a data line voltage according to the image data value, applying the generated data line voltage on a corresponding data line.

4. The method of claim 3 further comprising:

(f) measuring reaction curves of the pixels of the LCD panel switched from any gray scale value to other gray scale values in a frame period, and generating a standard table according to the reaction curves measured.

5. The method of claim 4 further comprising:

(g) measuring adjustment gray scale values of any gray scale value for different gammas;

(h) generating a plurality of tables except the standard table according to the adjustment gray scale values and the standard table;

6. The method of claim 3 further comprising:

(i) generating temperature compensation signals according to temperature of the LCD panel; and

(j) selecting the table from the standard table and the tables according to the gamma and the temperature compensation signals in step (d).

7. A driving circuit for driving an LCD, the LCD comprising:

an LCD panel, the liquid crystal panel comprising:

a plurality of scan lines;

a plurality of data lines; and

a plurality of pixels, each pixel being connected to a corresponding scan line and a corresponding data line, and each pixel having a switching device connected to the corresponding scan line and the corresponding data line;

the driving circuit comprising:

a scan line driving circuit for applying scan voltages to the scan lines;

an image signal terminal for receiving image data;

an image memory for storing the image data and delaying the image data for a frame period;

a memory for storing a plurality of tables;

a selector for selecting a table from the plurality of tables according to gamma;

a look up table for selecting an image data value from the selected table according to the current image data and the delayed image data; and

a data line driving circuit for generating a data voltage according to the image data value and applying the data voltage to a corresponding data line.

8. The driving circuit of claim 7 further comprising a thermal sensor for sensing temperature of the LCD panel and generating temperature compensation signals according to the temperature, and the selector selecting the table from the plurality of tables stored in the memory according to gamma and the temperature compensation signals.

* * * * *

专利名称(译)	液晶显示器的驱动电路及相关的驱动方法		
公开(公告)号	US20050099549A1	公开(公告)日	2005-05-12
申请号	US10/707384	申请日	2003-12-09
[标]申请(专利权)人(译)	陈诚JUNG 沉YUHREN CHIEN陈亮		
申请(专利权)人(译)	陈诚-JUNG 沉YUHREN CHIEN良辰		
当前申请(专利权)人(译)	VASTVIEW TECHNOLOGY INC.		
[标]发明人	CHEN CHENG JUNG SHEN YUHREN CHIEN LIANG CHEN		
发明人	CHEN, CHENG-JUNG SHEN, YUHREN CHIEN, LIANG-CHEN		
IPC分类号	G02F1/136 G09G3/36		
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优先权	092127999 2003-10-08 TW		
其他公开文献	US7148869		
外部链接	Espacenet USPTO		

摘要(译)

液晶显示器（LCD）的驱动方法包括：（a）测量LCD面板像素在帧周期内从任何灰度值切换到其他像素的反应曲线，并根据结果生成标准表，（b）测量调整灰度不同伽玛的任何灰度值的比例值，（c）根据调整灰度值和标准表生成多个表，（d）将扫描电压施加到扫描线，（e）从扫描线接收图像数据图像信号终端，（f）延迟帧周期的图像数据以产生延迟图像数据，（g）根据伽马从标准表和表中选择表，以及（h）从所选择的图像数据值中选择图像数据值表根据当前和延迟的图像数据产生要施加在相应数据线上的数据线电压。