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(54) **LIQUID CRYSTAL DISPLAY DRIVING APPARATUS AND METHOD THEREOF**

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(57) **ABSTRACT**

A liquid crystal display (LCD) driving method is provided. A pixel of the LCD is driven according to a precharge pixel value and a compensation pixel value both being generated from a pixel value during a precharge field and a compensation field respectively. A precharge driving voltage corresponding to the precharge pixel value, and a compensation driving voltage corresponding to the compensation pixel value is then determined and used to drive the pixel. The lightness of the pixel driven according to the precharge pixel value and the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the pixel value. The precharge field comes before the compensation field when the precharge pixel value is larger than the compensation pixel value, and the compensation field comes before the precharge field when the compensation pixel value is larger than the precharge pixel value.

34   100   30

I

11   11   11

T1   T2   T3   t

FIG. 1 (PRIOR ART)

Vd

T1   T2   T3   t

FIG. 2A (PRIOR ART)

L

21

21   22

22   22   21

T1   T2   T3   t

FIG. 2B (PRIOR ART)

FIG. 3A   (PRIOR ART)
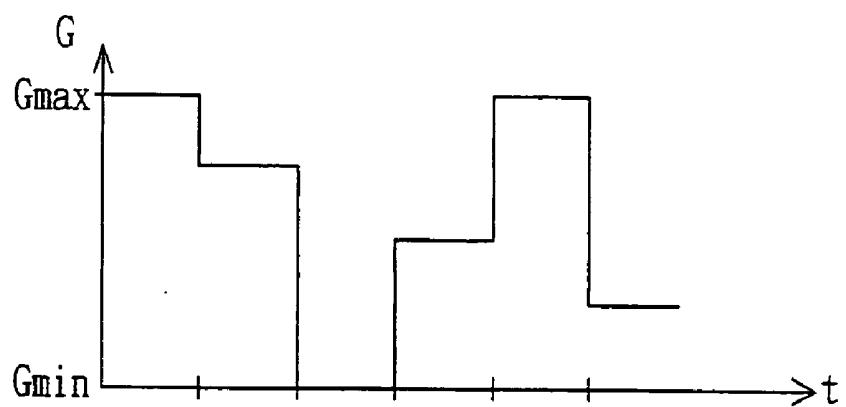
FIG. 3B   (PRIOR ART)
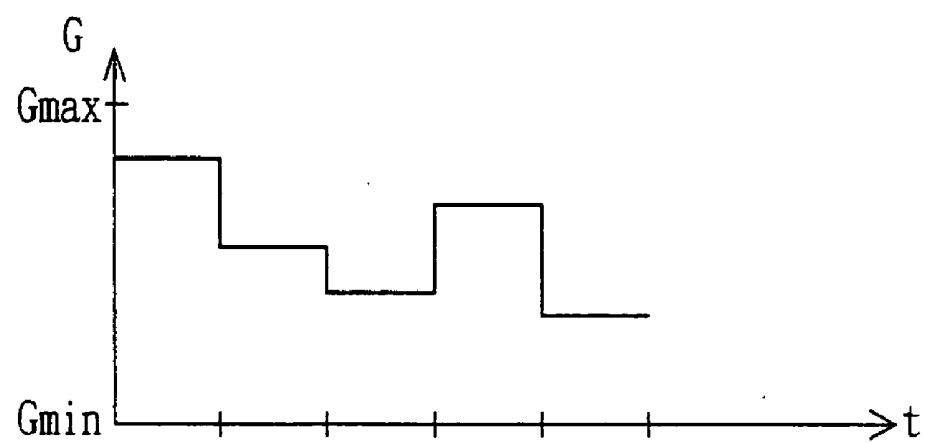
FIG. 3C(PRIOR ART)
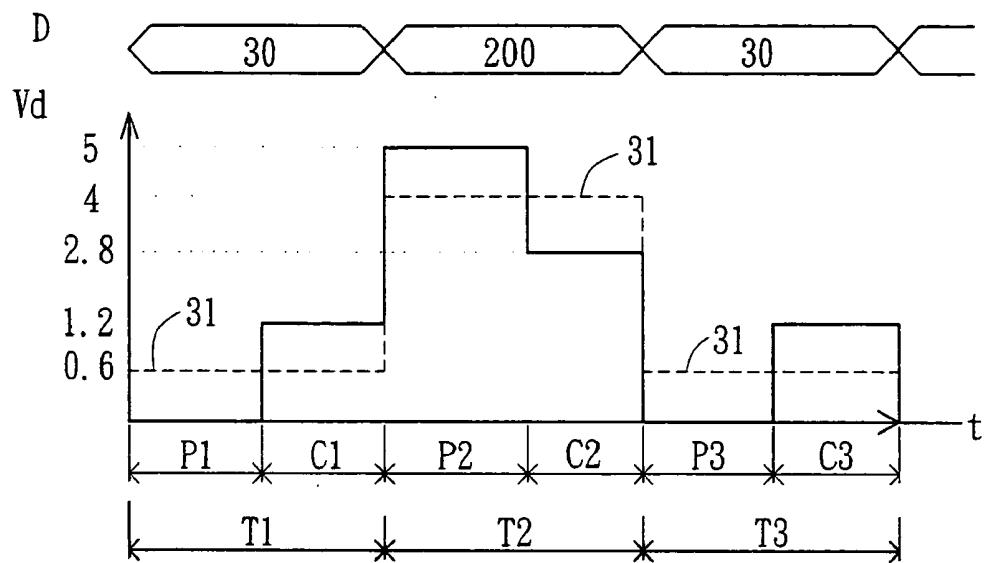
FIG. 4A
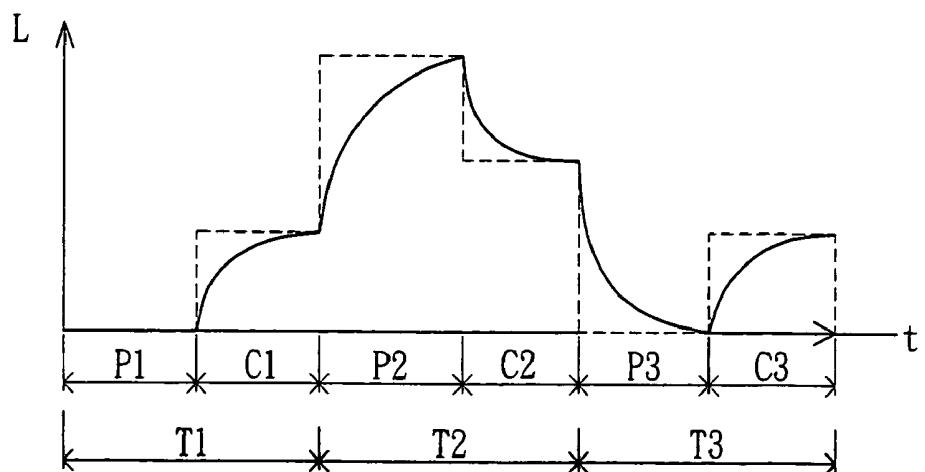
FIG. 4B
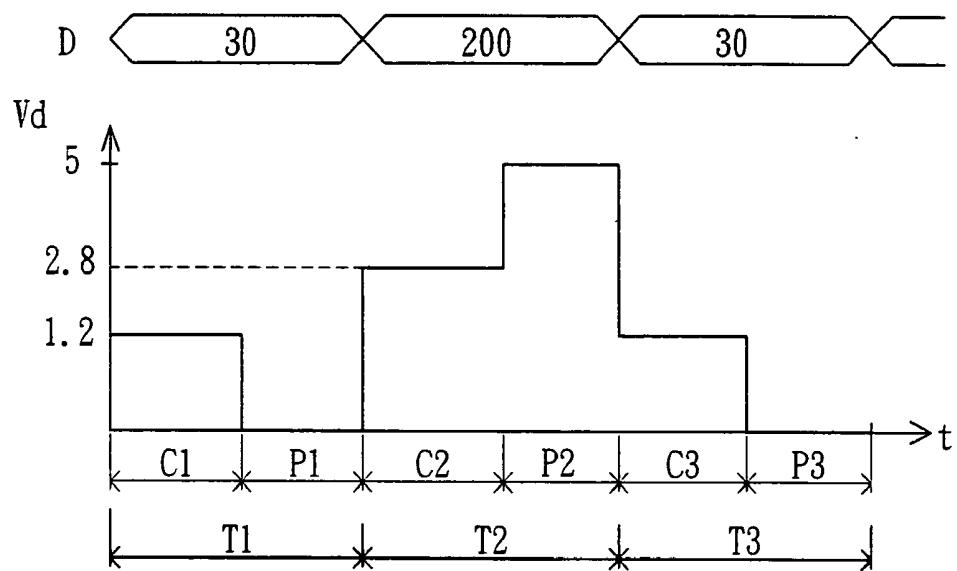
FIG. 5A
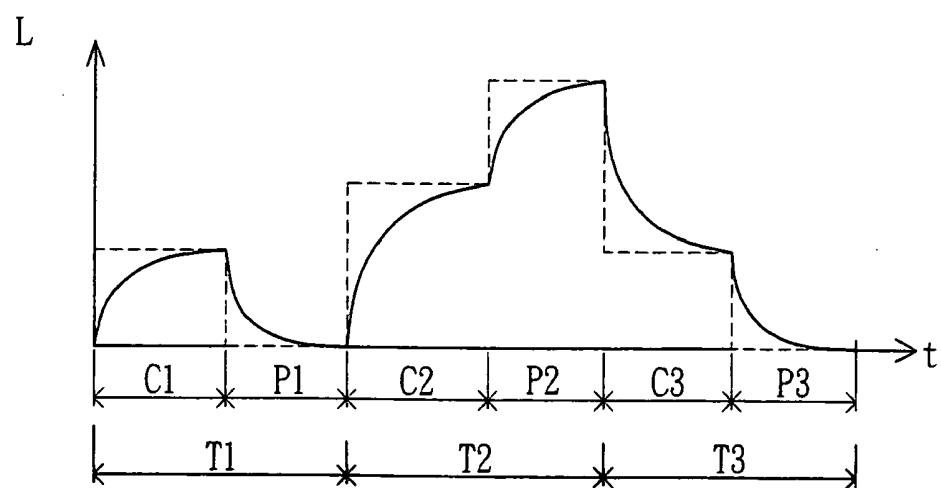
FIG. 5B
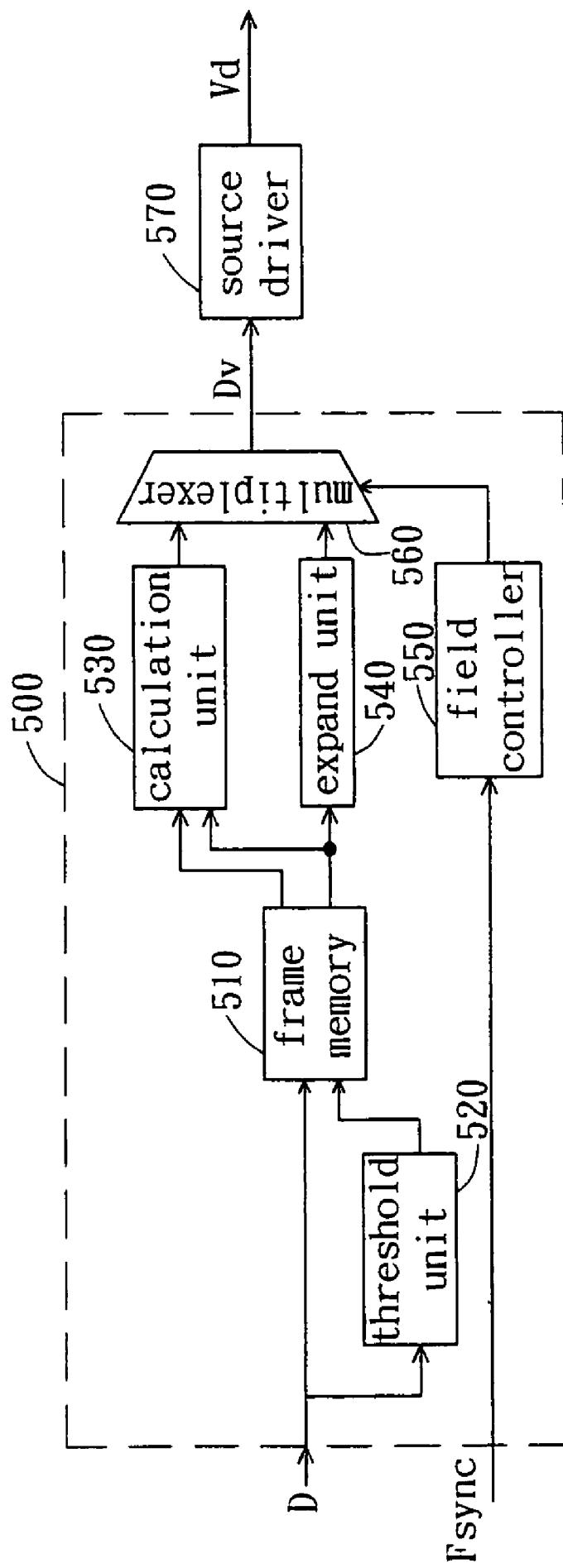
FIG. 6
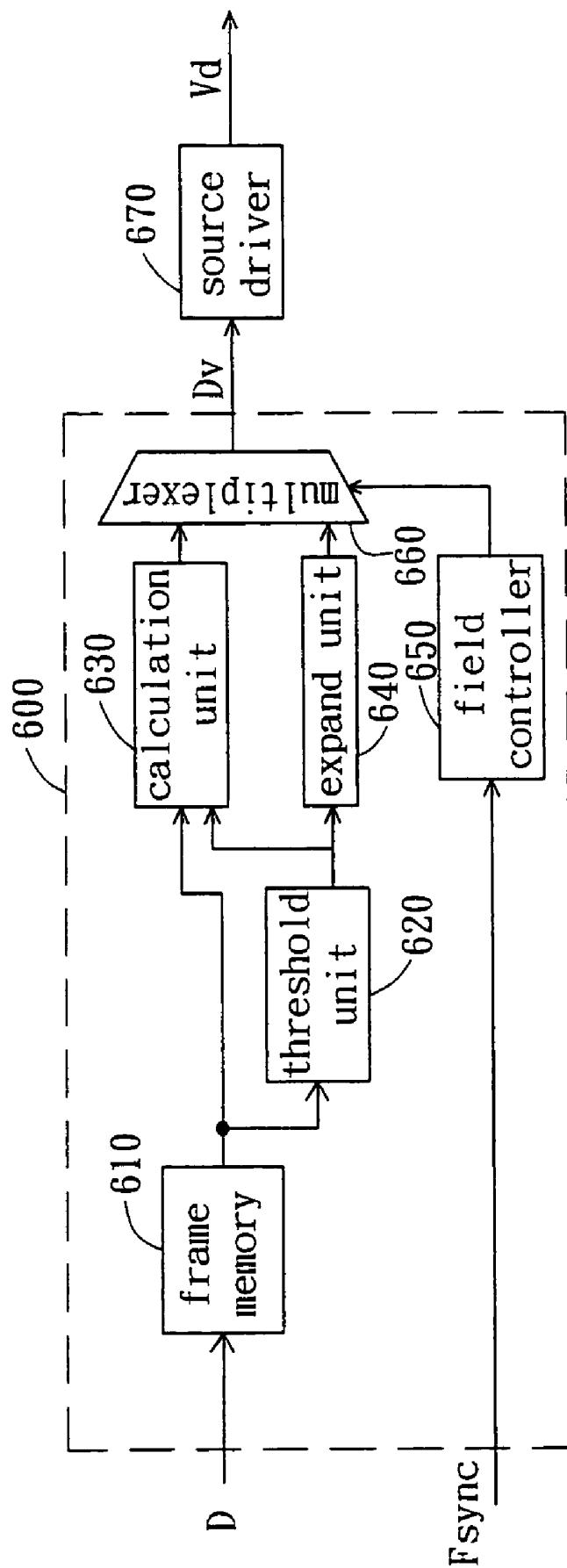
FIG. 7
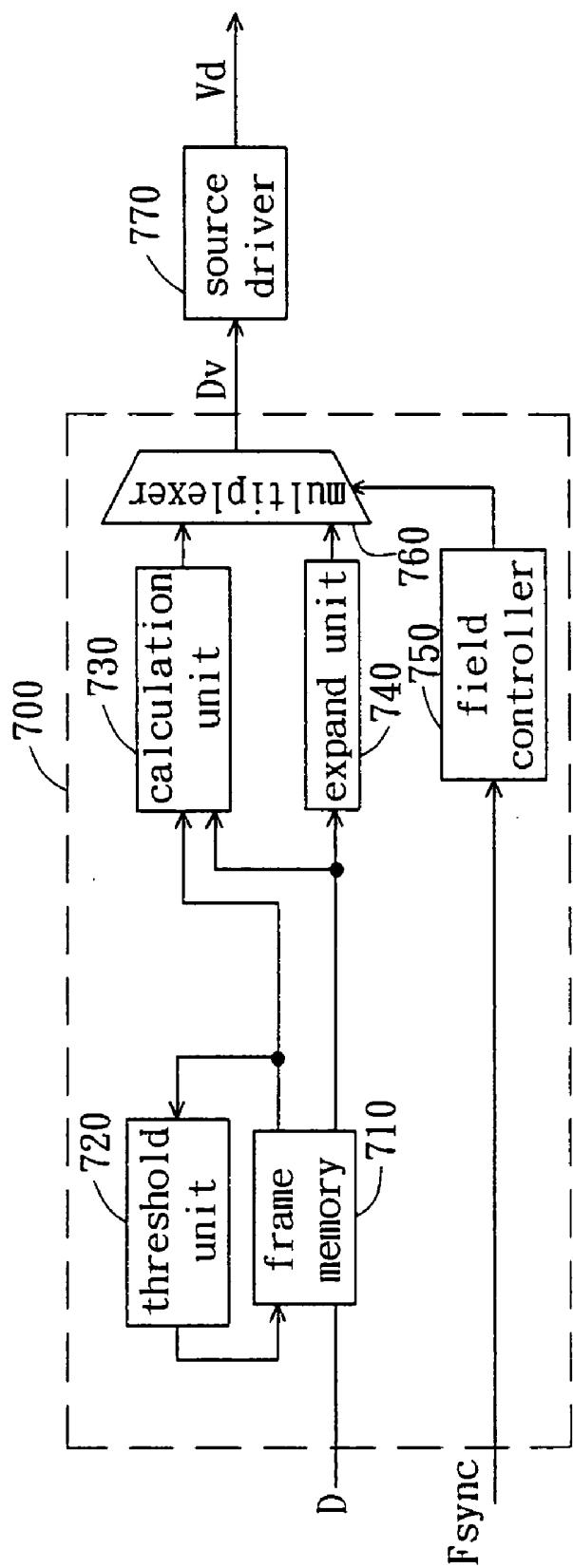
FIG. 8
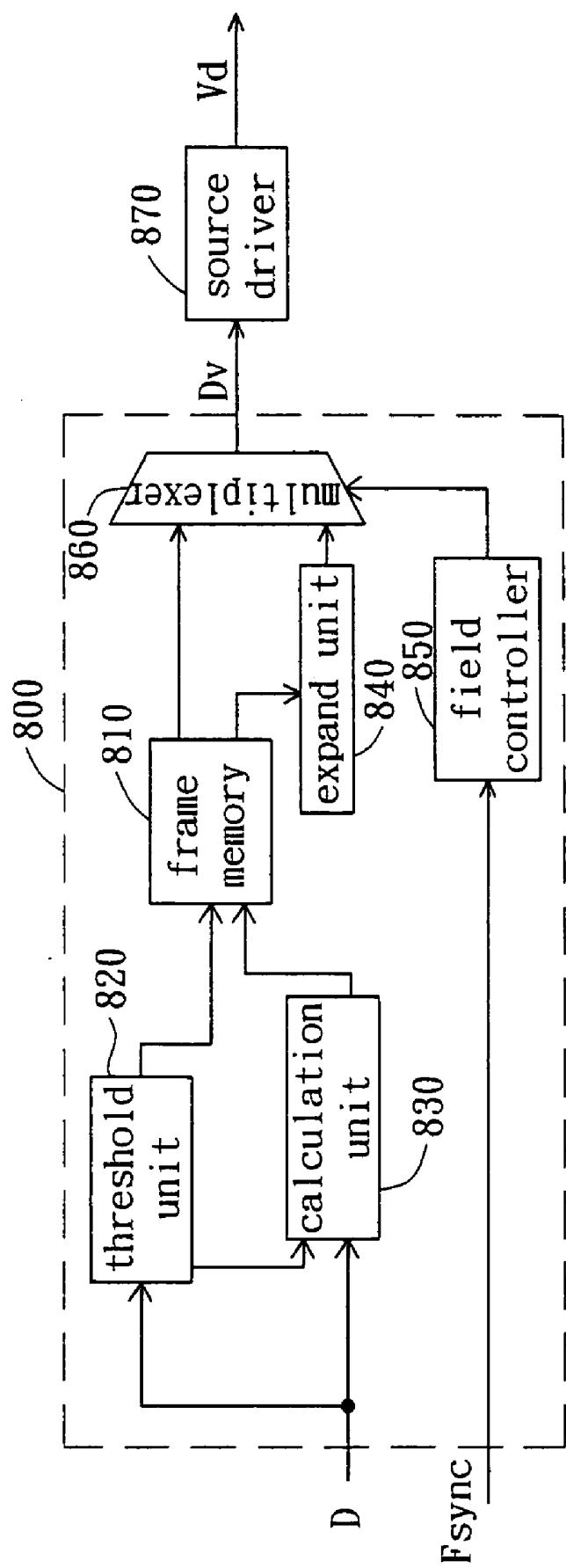
FIG. 9
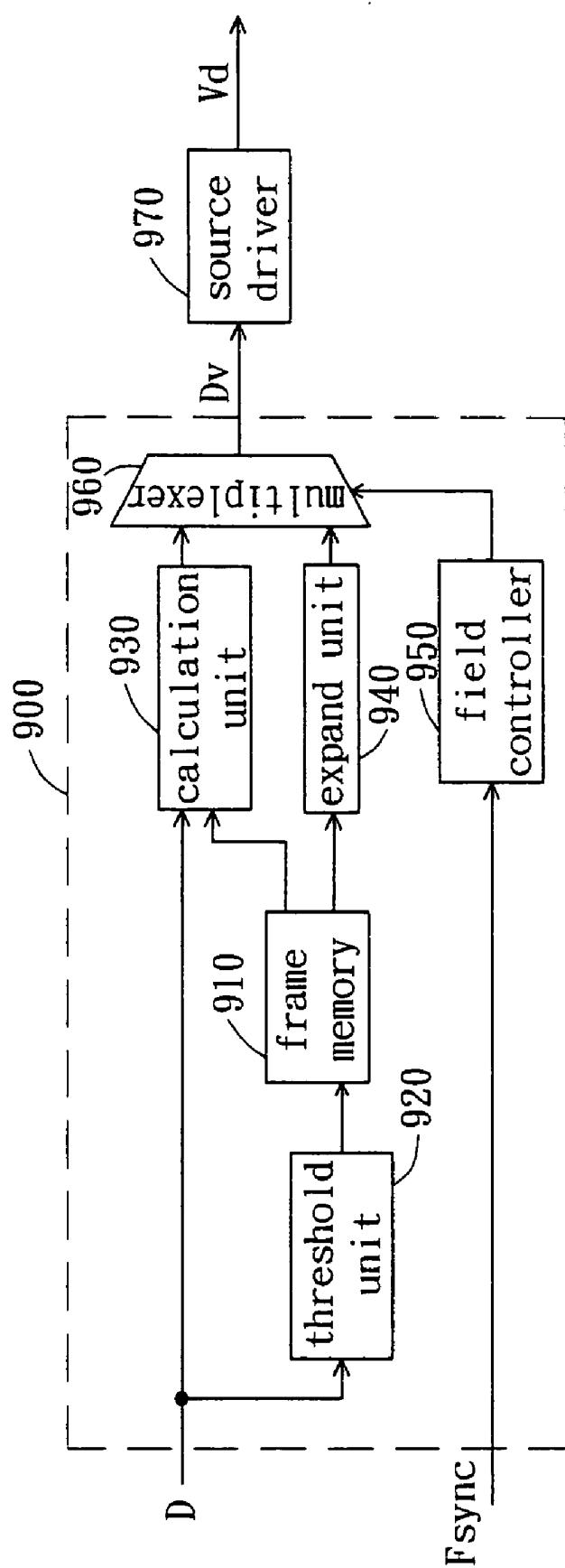
FIG. 10
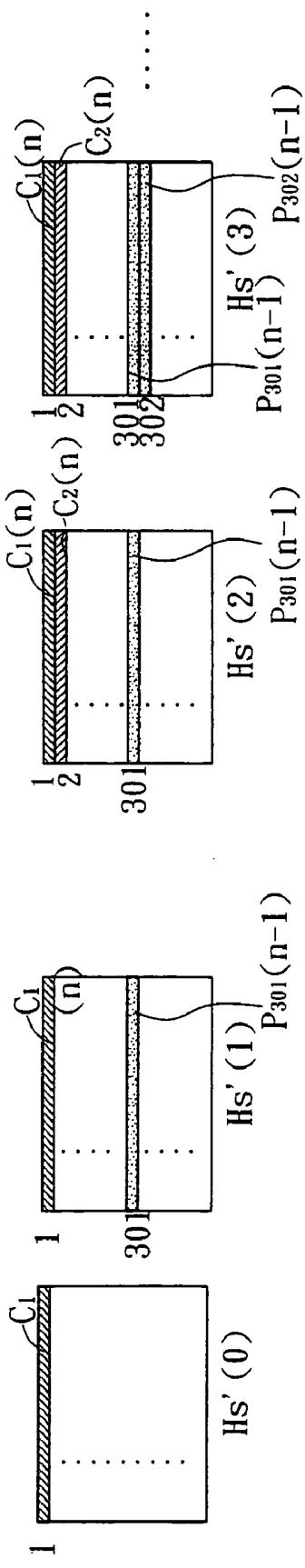
FIG. 11A
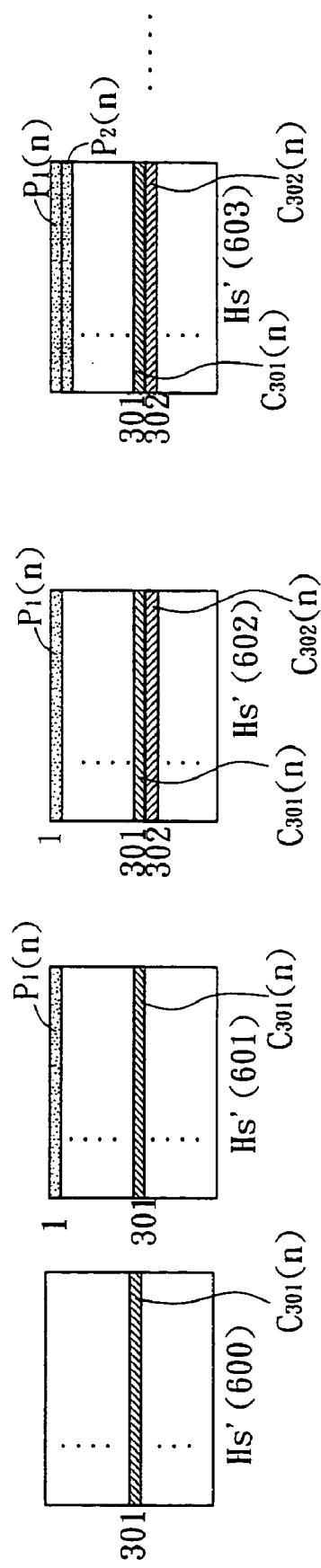
FIG. 11B
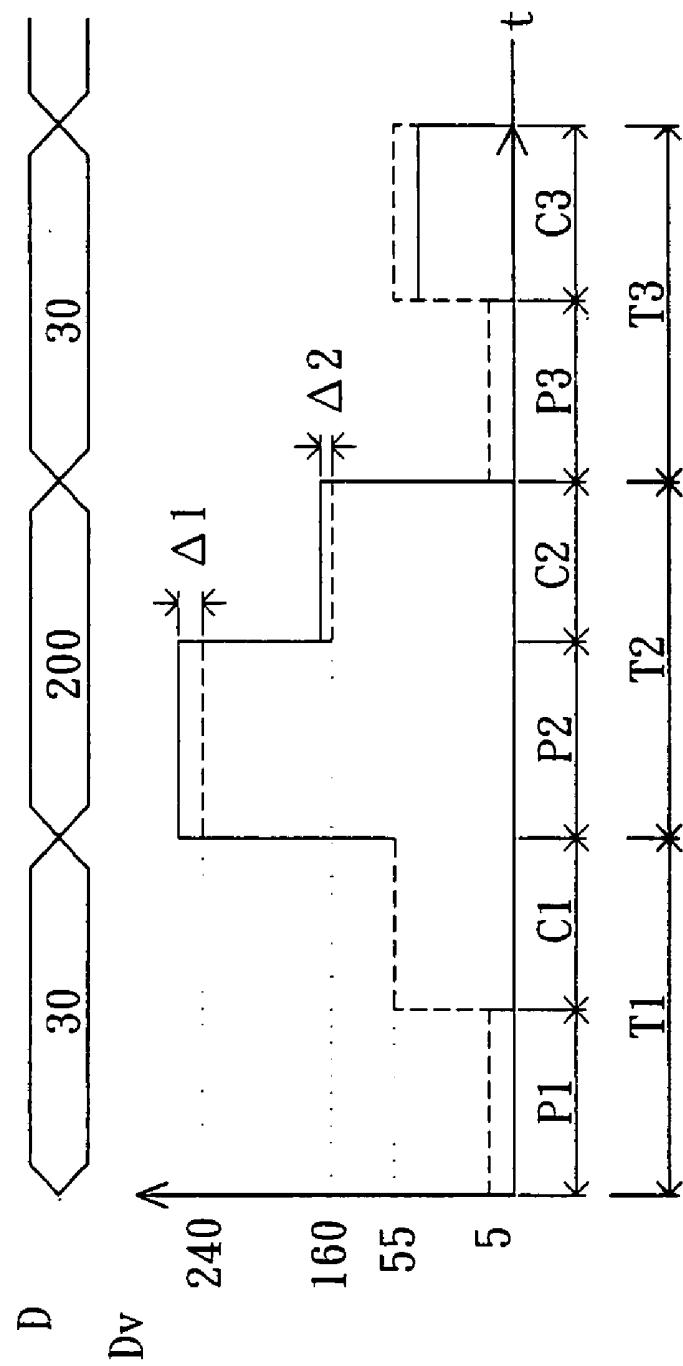
FIG. 12
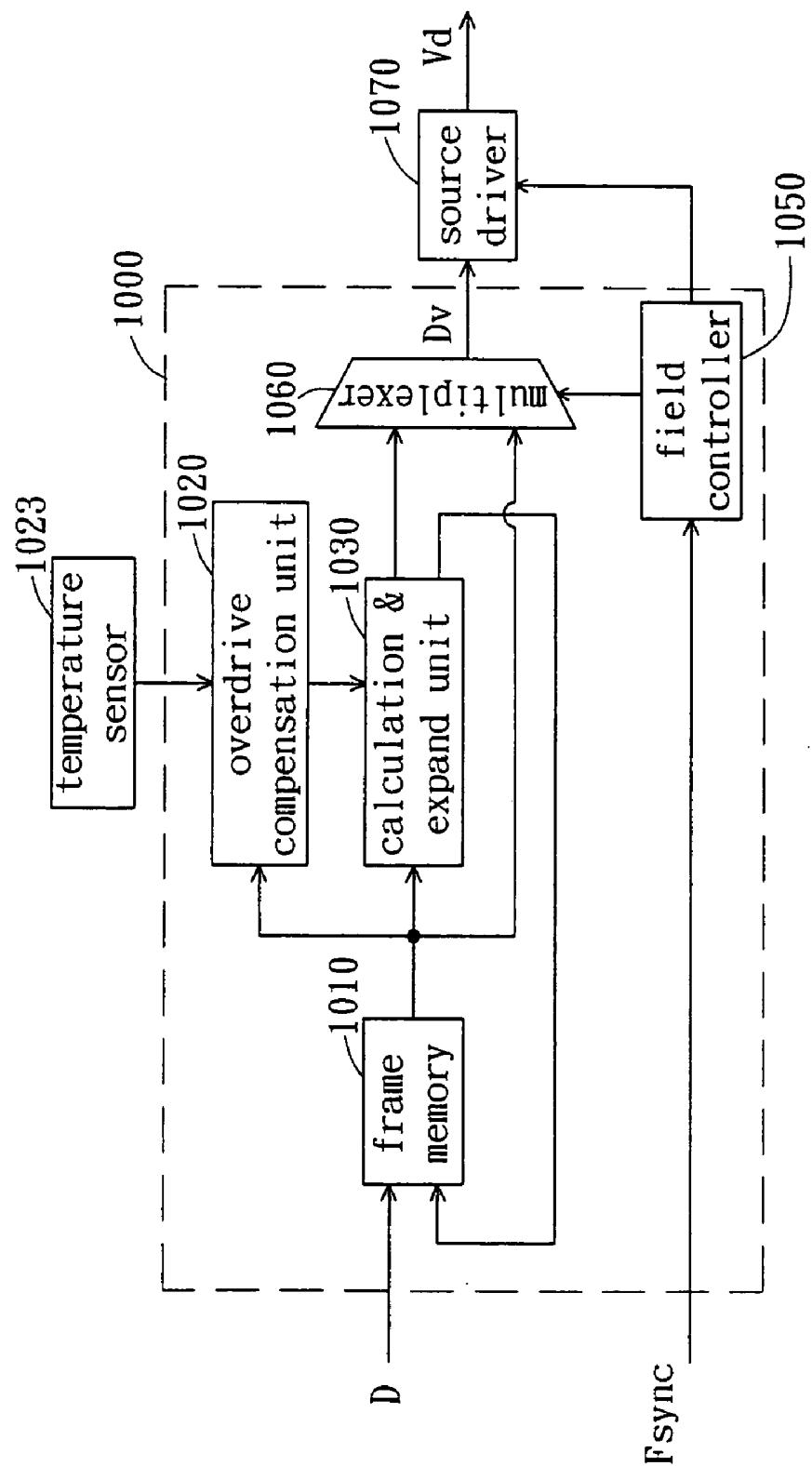
FIG. 13
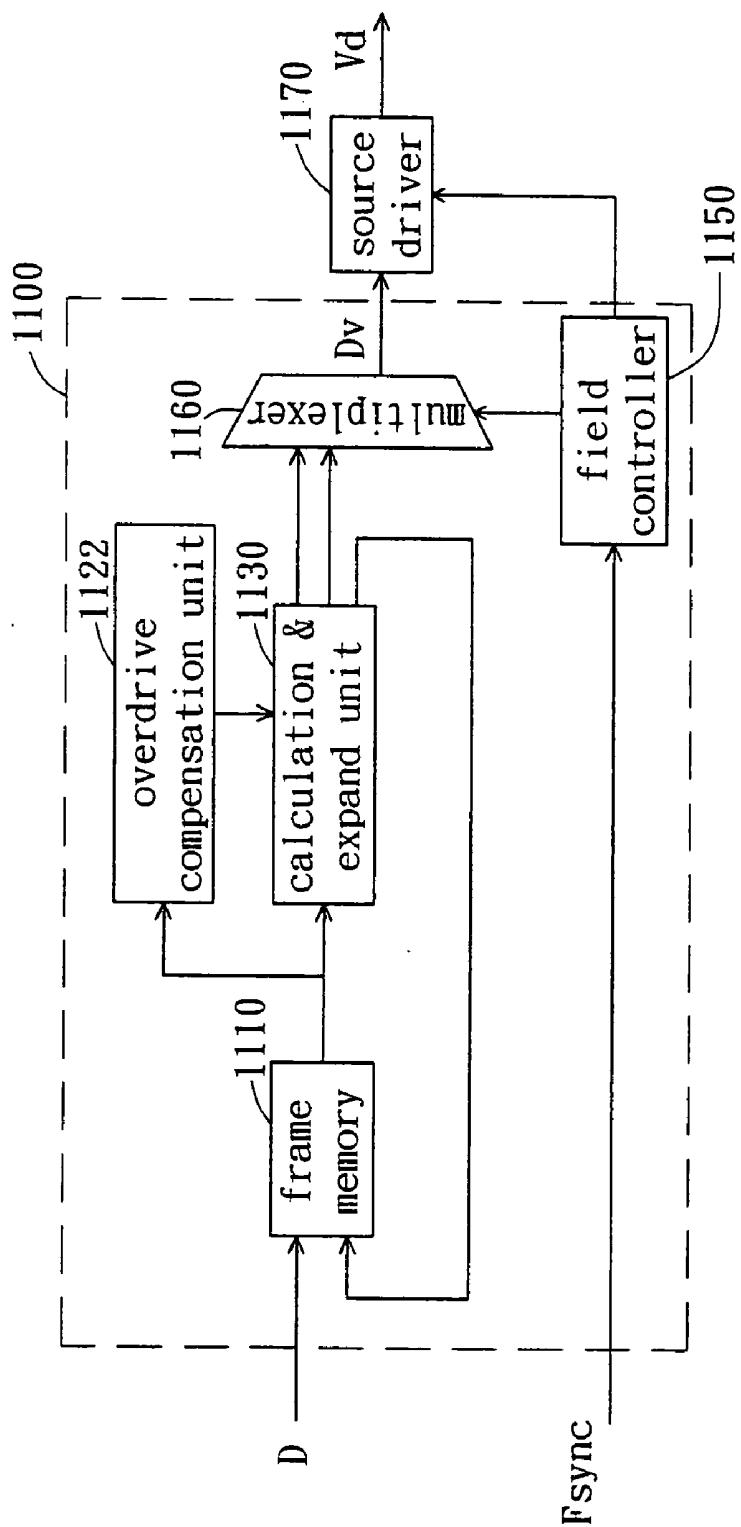
FIG. 14
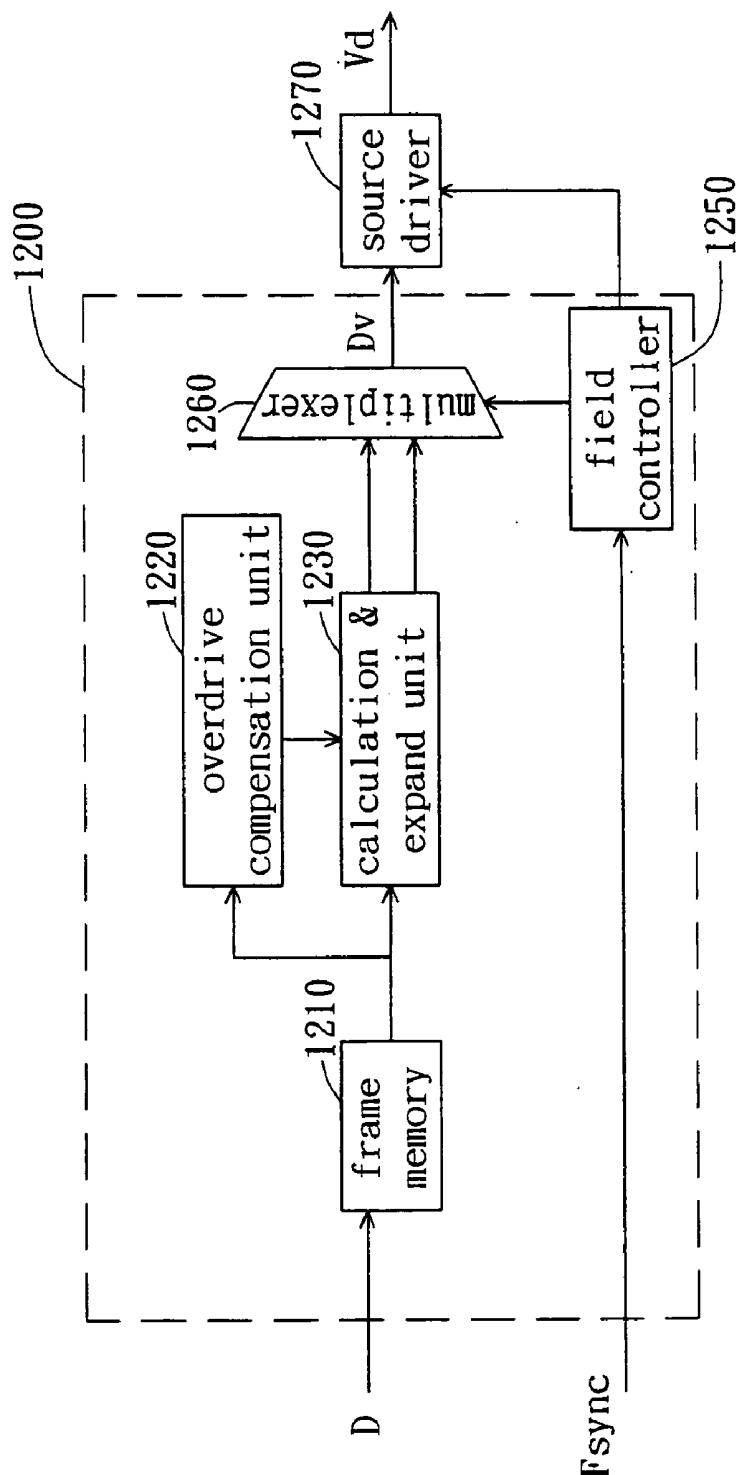
FIG. 15
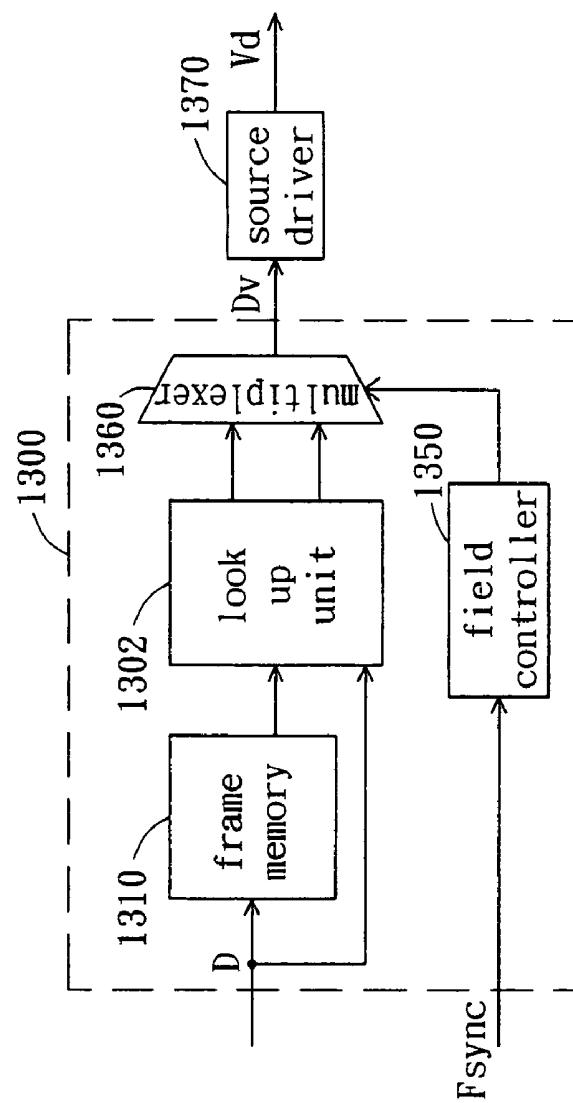
FIG. 16A

| input	output	
pixel value	precharge pixel value	compensation pixel value
0	0	0
1	0	0
2	0	1
3	0	3
4	0	9
...	...	...
...	...	...
251	250	255
252	252	255
253	253	255
254	254	255
255	255	255

FIG. 16B
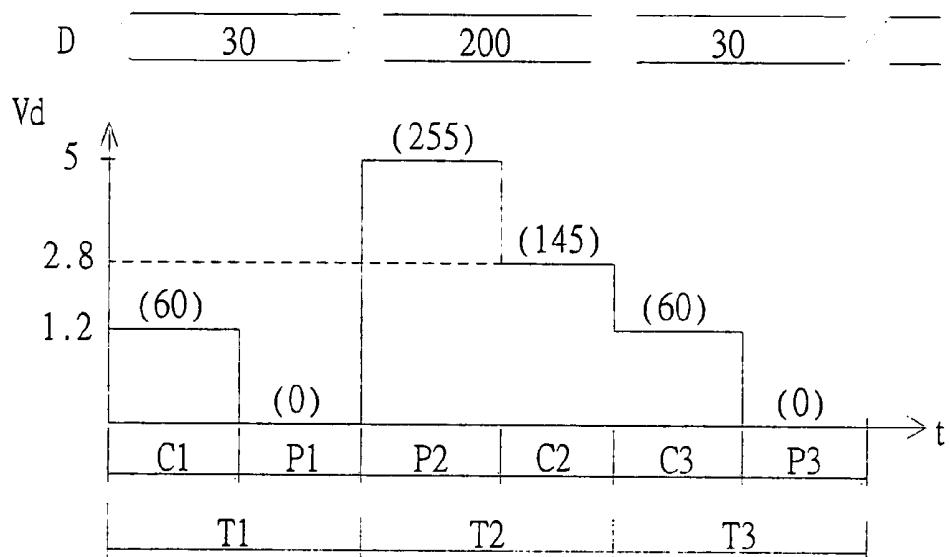
FIG. 17
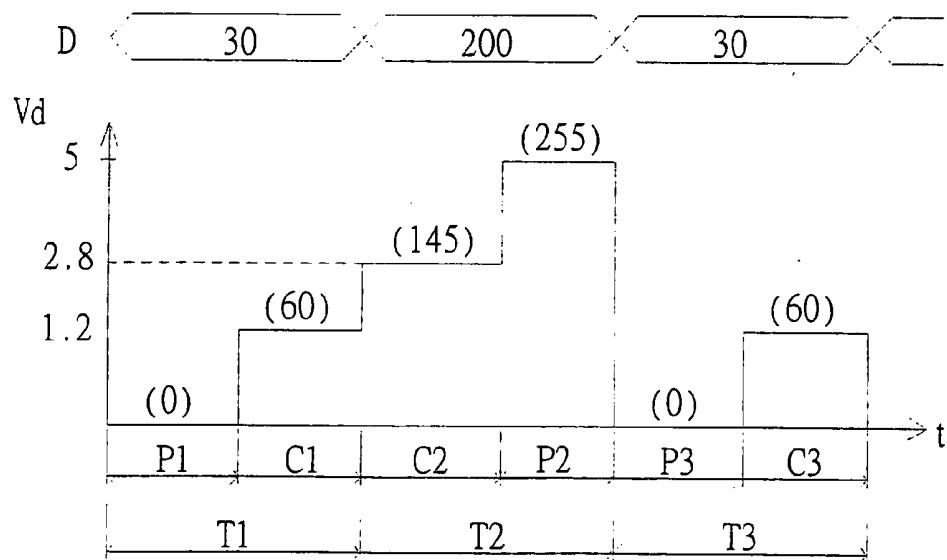
FIG. 18
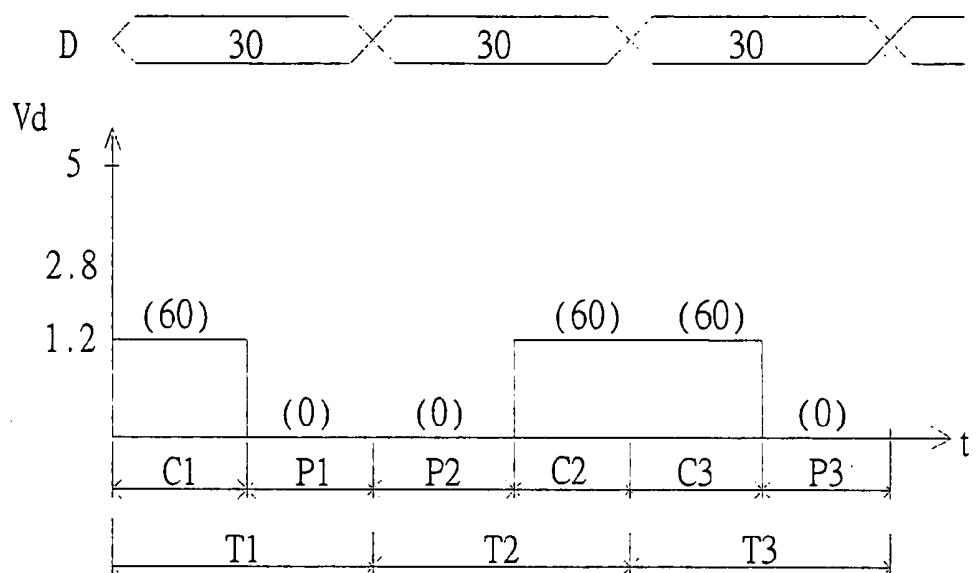
FIG. 19

LIQUID CRYSTAL DISPLAY DRIVING APPARATUS AND METHOD THEREOF

[0001] This application claims the benefit of Taiwan Patent Applications, Serial No. 092113907, filed May 22, 2003, and Serial No. 093111798, filed Apr. 27, 2004, the subject matter of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates in general to a liquid crystal display (LCD) driving apparatus and the method thereof, and in particular to an LCD driving apparatus and the method thereof having improved displaying quality.

[0004] 2. Description of the Related Art

[0005] Liquid crystal displays (LCDs) have been widely used for their characteristics of lightness and thinness. However, the LCDs have slow speed of responding, as compared with the traditional cathode ray tube (CRT) monitor. The LCD tends to have image residue as the dynamic images are displayed, while the CRT monitor does not.

[0006] The way that the CRT monitor displays the frames is called an impulse type. Each pixel only emits light at an instant during each frame period. Referring to FIG. 1, it shows the relation of lightness l for one pixel vs. time t of the CRT monitor. The pixel values D of this pixel at frame period T1, T2, and T3 are supposed to be respectively 34, 100, and 30. The illumination intensities of pluses 11 are controlled according to the pixel values D. The lightness of the present frame period will not affect that of the next frame period as a consequence of the impulse type, and thus the image residue is not existed and the response time is short.

[0007] The way that the LCD displays the frames is called a hold type. Each pixel value D emits constant light in one frame period. Referring to FIG. 2A, it shows the relation of time t and driving voltage Vd applied to the pixel according to the display of LCD. The pixel values D of the pixel at frame periods T1, T2, and T3 are supposed to be respectively 34, 100, and 30. The driving voltages Vd at frame period T1, T2, and T3 are respectively determined according to those pixel values D.

[0008] Referring to FIG. 2B, it shows the diagram of the lightness L of the pixel vs. time t. The lightness line 21 is the ideal lightness of the pixel according to the driving voltage Vd of FIG. 2A. In reality, the response speed of the liquid crystal molecule is slower than that of the electric field, and thus a response time is required for the pixel to reach the proposed lightness. The lightness line 22 is the actual lightness of the pixel according to the driving voltage Vd of FIG. 2A. The quality of image is lowered with the image residue caused by the slow response.

[0009] The above problem can be improved, for example, by over-driving method. If the pixel value of the present frame period to be displayed is larger than that of the previous one, the driving voltage larger than that to be displayed is applied to the pixel. If the pixel value of the present frame period to be displayed is smaller than that of the previous one, the driving voltage smaller than that to be displayed is applied to the pixel.

[0010] However, the display quality of LCD is still not as satisfying as the CRT even if the liquid crystal molecule

responds to the applied driving voltage in real time due to the hold type. For example, the image at the beginning of the frame period T3 will overlaps with the image of the frame period T2 by human's eye, when the responding is supposed to be real time according to the lightness lines 21 of FIG. 2B. Therefore, not only the low speed of responding, but the hold type also decreases the displaying quality of the LCD.

SUMMARY OF THE INVENTION

[0011] It is therefore an object of the invention to provide a liquid crystal display (LCD) driving apparatus and the method thereof having improved displaying quality.

[0012] According to the object of the present invention, a method for driving a liquid crystal display (LCD) is provided. The LCD is adapted to receive a pixel value and to drive a pixel of the LCD according to the pixel value during a frame period. The frame period is divided into a precharge field and a compensation field. The method includes the following steps. First, decide a precharge pixel value to be either a predetermined first pixel value or a predetermined second pixel value according to the pixel value. Then, decide a compensation pixel value. After that, drive the pixel according to the precharge value and the compensation pixel value, including: determining a precharge driving voltage corresponding to the precharge pixel value; determining a compensation driving voltage corresponding to the compensation pixel value; driving the pixel according to the precharge driving voltage during the precharge field; and driving the pixel according to the compensation driving voltage during the compensation field. At the driving step, the lightness of the pixel driven according to the precharge pixel value and the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the pixel value. The precharge field comes before the compensation field when the precharge pixel value is larger than the compensation pixel value, and the compensation field comes before the precharge field when the compensation pixel value is larger than the precharge pixel value.

[0013] According to the object of the present invention, a method for driving a liquid crystal display (LCD) is provided. The LCD is adapted to receive a pixel value and to drive a pixel of the LCD according to the pixel value during a frame period. The frame period is divided into a precharge field and a compensation field. The method includes the following steps. First, decide a precharge pixel value to be either a predetermined first pixel value or a predetermined second pixel value according to the pixel value. Then, decide a compensation pixel value. After that, drive the pixel according to the precharge value and the compensation pixel value, including: determining a precharge driving voltage corresponding to the precharge pixel value; determining a compensation driving voltage corresponding to the compensation pixel value; driving the pixel according to the precharge driving voltage during the precharge field; and driving the pixel according to the compensation driving voltage during the compensation field. At the driving step, the lightness of the pixel driven according to the precharge pixel value and the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the pixel value. The precharge field comes before the compensation field when the precharge pixel value is smaller than the compensation pixel value, and the compensation field comes before the precharge field when the compensation pixel value is smaller than the precharge pixel value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Other objects, features, and advantages of the invention will become apparent from the following detailed description of the preferred but non-limiting embodiments. The description is made with reference to the accompanying drawings in which:

[0015] FIG. 1 shows the relation of lightness l for one pixel and time t according to the display of a CRT.

[0016] FIG. 2A shows the relation of time t and driving voltage Vd applied to the pixel according to the display of LCD.

[0017] FIG. 2B shows the relation of time t and the lightness L for pixel provided with the voltages of FIG. 2A.

[0018] FIG. 3A shows the situation wherein the liquid crystal molecules have the shortest response time.

[0019] FIG. 3B shows the situation wherein the liquid crystal molecules have the intermediate response time.

[0020] FIG. 3C shows the situation wherein the liquid crystal molecules have the longest response time.

[0021] FIG. 4A shows the driving voltage according to a first embodiment of the driving method for an LCD.

[0022] FIG. 4B shows the lightness of the pixel, to which the driving voltages of FIG. 4A are applied.

[0023] FIG. 5A shows the driving voltage of the other driving method for an LCD, wherein the compensation field is prior to the precharge field.

[0024] FIG. 5B shows the lightness of the pixel, to which the driving voltages of FIG. 5A are applied.

[0025] FIG. 6 shows the block diagram of an LCD driving apparatus according to a second embodiment of the present invention.

[0026] FIG. 7 shows the block diagram of an LCD driving apparatus according to a third embodiment of the present invention.

[0027] FIG. 8 shows the block diagram of an LCD driving apparatus according to a fourth embodiment of the present invention.

[0028] FIG. 9 shows the block diagram of an LCD driving apparatus according to a fifth embodiment of the present invention.

[0029] FIG. 10 shows the block diagram of an LCD driving apparatus according to a sixth embodiment of the present invention.

[0030] FIG. 11A shows the scanning process while receiving the pixel values for the upper part of the nth frame.

[0031] FIG. 11B shows the scanning process while receiving the pixel values for the lower part of the nth frame.

[0032] FIG. 12 shows the driving voltage of the driving method for an LCD according to a seventh embodiment of the invention.

[0033] FIG. 13 shows the block diagram of an LCD driving apparatus according to an eighth embodiment of the present invention.

[0034] FIG. 14 shows the block diagram of an LCD driving apparatus according to a ninth embodiment of the present invention.

[0035] FIG. 15 shows the block diagram of an LCD driving apparatus according to a tenth embodiment of the present invention.

[0036] FIG. 16A shows the block diagram of an LCD driving apparatus according to an eleventh embodiment of the present invention.

[0037] FIG. 16B shows the table used by the look up unit.

[0038] FIG. 17 shows the driving voltage according to one example of sequence of the precharge field P and the compensation field C.

[0039] FIG. 18 shows the driving voltage according to another example of sequence of the precharge field P and the compensation field C.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0040] The responding speed of the liquid crystal molecule is related to the present state and the target state of the liquid crystal molecule. Referring to FIG. 3A, it shows the situation wherein the liquid crystal molecules have the shortest response time. When the pixel value G rises from the minimum pixel value Gmin to the maximum pixel value Gmax, or descends from the maximum pixel value Gmax to the minimum pixel value Gmin, the liquid crystal molecules have the shortest response time.

[0041] Referring to FIG. 3B, it shows the situation wherein the liquid crystal molecules have the intermediate response time. When the pixel value G rises from the minimum pixel value Gmin to the intermediate pixel value, or from the intermediate pixel value to the maximum pixel value Gmax, or falls from the maximum pixel value Gmax to the intermediate pixel value, or from the intermediate pixel value to the minimum pixel value Gmin, the liquid crystal molecules have a moderate response time.

[0042] Referring to FIG. 3C, it shows the situation where the liquid crystal molecules have the longest response time. When the pixel value G changes from one intermediate pixel value to the other intermediate pixel value, the liquid crystal molecules have the longest response time. The situation of FIG. 3C should be avoided to enhance the display quality.

[0043] In the following embodiment, the refresh rate of the LCD is assumed to be 60 Hz, and the resolution is assumed to be 800×600. The displaying process of a traditional liquid crystal display (LCD) is controlled by a vertical synchronization signal Vs and a horizontal synchronization signal Hs. There are 60 frames to be displayed in one second according to the vertical synchronization signal Vs having the frequency of 60 Hz, which is denoted as f(Vs), and thus the corresponding frame period is $\frac{1}{60}$=16.7 ms. Each frame has 600 horizontal lines, which are scanned orderly by the control of Hs signal, and thus the frequency of the Hs signal is f(Hs)=600*f(Vs)=36,000 Hz. Each horizontal line has 800 points, and each point includes a red, blue, and a green pixel. So that, each horizontal line has 800*3=2400 pixels. The frequency of the pixel clock signal Cp, for controlling the input of the pixel bit stream into the LCD, is f(Cp)= 2400*f(Hs)=86,400,000 Hz. The pixel value is supposed to

have 8 bits, 0~255 gray levels, and the corresponding driving voltage is 0~5V. The relation of the pixel value and the driving voltage is not necessarily linear, and is obtained by looking up a table, for example.

[0044] Referring to FIG. 4A, it shows the driving voltage of the driving method for an LCD according to a first embodiment of the invention. The pixel values D in the frame periods T1, T2, and T3 are supposed to be respectively 30, 200, and 30. By conventional driving method, the corresponding driving voltages in the frame period T1, T2, and T3 are, for instance, 0.6V, 4V, and 0.6V, as shown by dash line 31 in FIG. 4A. However, the conventional method has the disadvantage of long response time.

[0045] The first embodiment of the present invention divides a frame period into a compensation field C and a precharge field P prior to the compensation field. The precharge pixel value of the precharge field P is either a predetermined high pixel value Gmax, which is for example the maximum pixel value in the first embodiment, or a predetermined low pixel value Gmin, which is for example the minimum pixel value in the first embodiment. The compensation pixel value corresponding to the compensation field is determined according to the pixel value and the precharge pixel value. In the first embodiment, the pixel value is approximately the average of the precharge field P and the corresponding compensation field C.

[0046] The frame period T1 is divided into a precharge field P1 and a compensation field C1; the frame period T2 is divided into a precharge field P2 and a compensation field C2; the frame period T3 is divided into a precharge field P3 and a compensation field C3.

[0047] First, a precharge pixel value of the precharge field P is determined. If the pixel value of the frame period is larger than a reference value, the precharge pixel value will be the predetermined high pixel value Gmax. If the pixel value of the frame period is smaller than the reference value, the precharge pixel value will be the predetermined low pixel value Gmin. The reference value is adjusted according to the characteristic of the LCD. Here, the reference value is supposed to be 128.

[0048] The pixel value of the frame period T1 is 30, being smaller than the reference value of 128, so the precharge pixel value of the precharge field P1 is the predetermined low pixel value Gmin of 0. Hence, the compensation pixel value of the compensation field C1 is determined to be 60 so that the average of the compensation pixel value and the precharge pixel value is substantially the pixel value of frame period T1.

[0049] The pixel value of the frame period T2 is 200, being larger than the reference value of 128, so that the precharge pixel value of the precharge field P2 is the predetermined high pixel value Gmax of 255. The compensation pixel value of the compensation field C2 is accordingly determined to be 145, so that the pixel value of the frame period T2, being 200, is the average of the precharge pixel value of the precharge field P2 and the compensation pixel value of the compensation field C2.

[0050] The pixel value of the frame period T3 is 30, being smaller than the reference value of 128, such that the precharge pixel value of the precharge field P3 is determined to be the predetermined low pixel value Gmin of 0. The

compensation pixel value of the compensation field C3 is accordingly determined to be 60, so that the pixel of the frame period T3, being 30, is the average of the precharge pixel value of the precharge field P3 and the compensation pixel value of the compensation field C3.

[0051] The driving voltages are decided according to the precharge pixel value and the compensation pixel value by, for instance, looking up a table. The driving voltages in each field of this embodiment is 0V, 1.2V, 5V, 2.8V, 0V, 1.2V, as shown in FIG. 4A.

[0052] Referring to FIG. 4B, it shows the lightness of the pixel to which the driving voltages of FIG. 4A are applied. The dash line represents the ideal lightness of the pixel, and the solid line represents the real lightness of the pixel. For example, consider the frame period T2. The lightness of the pixel rises to the maximum during the precharge field P2. The rising time of this embodiment is shorter than that of the conventional method as a result of the larger driving voltage of this embodiment than that of the conventional one. The lightness of the pixel begins to fall during the compensation field C2. The falling time of this embodiment is shorter than that of the conventional method due to the smaller driving voltage of this embodiment than that of the conventional one. Moreover, the curve of the lightness for the frame period T2 is more like the display of the impulse type, such that the effect of the image residue is diminished. Furthermore, the long response time situation, as shown is FIG. 3C, is prevented either by approaching the intermediate pixel value from the predetermined high or low pixel value, or by starting from the intermediate pixel value to the predetermined high or low pixel value.

[0053] The predetermined high or low pixel value is not necessarily the maximum or the minimum pixel value and is dependent on the characteristics of the LCD.

[0054] Take frame period T2 for example. The lightness of frame period T2, which is the result of the lightness of precharge field P2 and that of the compensation field C2, is substantially equal to the lightness if the pixel is driven by the conventional method.

[0055] Referring to FIG. 5A, it shows the driving voltage of the other driving method for an LCD, wherein the compensation field is prior to the precharge field. The pixel values D in the frame period T1, T2, and T3 are supposed to be respectively 30, 200, and 30.

[0056] The frame period T1 is divided into a compensation field C1 and a precharge field P1; the frame period T2 is divided into a precharge field P2 and a compensation field C2; the frame period T3 is divided into a precharge field P3 and a compensation field C3.

[0057] The pixel value of the frame period T1 is 30, being smaller than the reference value of 128, so that the precharge pixel value of the precharge field P1 is determined to be the predetermined low pixel value Gmin of 0. The compensation pixel value of the compensation field C1 is accordingly determined to be 60, so that the pixel value for the frame period T1, being 30, is the average of the precharge pixel value of the precharge field P1 and the compensation pixel value of the compensation field C1.

[0058] The pixel value of the frame period T2 is 200, being larger than the reference value of 128, so that the

precharge pixel value of the precharge field P2 is determined to be the predetermined high pixel value Gmax of 255. The compensation pixel value of the compensation field C2 is thereby determined to be 145, so that the pixel value of the frame period T2, being 200, is the average of the precharge pixel value of the precharge field P2 and the compensation pixel value of the compensation field C2.

[0059] The pixel value of the frame period T3 is 30, being smaller than the reference value of 128, so that the precharge pixel value of the precharge field P3 is determined to be the predetermined low pixel value Gmin of 0. The compensation pixel value of the compensation field C3 is thereby determined to be 60, so that the pixel value of the frame period T3, being 30, is the average of the precharge pixel value of the precharge field P3 and the compensation pixel value of the compensation field C3.

[0060] The driving voltage is decided according to the precharge pixel value and the compensation pixel value by, for instance, looking up a table. The driving voltage in each field of this embodiment is 1.2V, 0V, 2.8V, 5V, 1.2V, and 0V, as shown in FIG. 5A.

[0061] Referring to FIG. 5B, it shows the lightness of the pixel, to which the driving voltages of FIG. 5A are applied. The dashed line represents the ideal lightness of the pixel, and the solid line represents the real lightness of the pixel. The longest response time situation, as shown in FIG. 3C, is avoided in this embodiment by either approaching the intermediate pixel value from the predetermined high or low pixel value, or by starting from the intermediate pixel value to the predetermined high or low pixel value.

[0062] Referring to FIG. 6, it shows the block diagram of an LCD driving apparatus according to a second embodiment of the present invention. The driving apparatus 500 includes a frame memory 510, a mathematic unit, and a field controller 550. The mathematic unit includes a threshold unit 520, a calculation unit 530, an expand unit 540, and a multiplexer 560. The LCD driving apparatus 500 receives a pixel value D and outputs driving value Dv, which is either the precharge pixel value or the compensation pixel value. Then, the source driver 570 thereby outputs driving voltage Vd to drive the LCD.

[0063] For example, consider the LCD having the refresh rate of 60 Hz, for which 60 frames are displayed in each second. The pixel value D is inputted into the LCD driving apparatus 500 according to the above-mentioned pixel clock signal Cp. The LCD driving apparatus 500 outputs the driving values Dv according to the pixel clock signal Cp', whose frequency is double of the pixel clock signal Cp, because that one frame period is divided into a compensation field and a precharge field.

[0064] First, the LCD driving apparatus 500 receives the pixel value D, saves the pixel value D in the frame memory 510, and sends the pixel value D to the threshold unit 520. The threshold unit 520 compares the pixel value D with a reference value; if the pixel value D is larger than the reference value, a threshold value from the threshold unit 520 will be a first value and be saved in the frame memory 510; otherwise, it will be a second value and be saved in the frame memory 510.

[0065] Then, the calculation unit 530 outputs a compensation pixel value according to the pixel value D and the

threshold value from the frame memory 510. If the threshold value is the second value, the compensation driving voltage is determined according to the double of the pixel value D. Otherwise, the compensation voltage is determined according to the result of double of the pixel value D minus the predetermined high pixel value.

[0066] The expand unit 540 receives the threshold value from the frame memory 510 and outputs a precharge pixel value. If the threshold value is the first value, the precharge pixel value will be the predetermined high pixel value; otherwise, it will be the predetermined low pixel value. The field controller 550 controls the multiplexer 560 to output the precharge pixel value or a compensation pixel value according to the second synchronization signal derived from the first synchronization signal Fsync. The sequence of the precharge field and the compensation field is decided by the field controller 550.

[0067] Referring to FIG. 7, it shows the block diagram of an LCD driving apparatus according to a third embodiment of the present invention. The LCD driving apparatus 600 includes a frame memory 610, a mathematic unit, and a field controller 650. The mathematic unit includes a threshold unit 620, a calculation unit 630, an expand unit 640, and a multiplexer 660. The LCD driving apparatus 600 receives the pixel value D and outputs a driving value Dv, which is either the precharge pixel value or the compensation pixel value, and thereby the source driver 670 outputs driving voltage Vd to drive the LCD.

[0068] For example, consider the LCD having the refresh rate of 60 Hz, for which 60 frames are displayed in each second. The pixel value D is inputted into the LCD driving apparatus 600 according to the pixel clock signal Cp. The LCD driving apparatus 600 outputs of the driving voltage Vd according to the pixel clock signal Cp', whose frequency is double of the pixel clock signal Cp, because that one frame period is divided into the compensation field and the precharge field.

[0069] First, the driving apparatus 600 receives the pixel value D, and saves the pixel value D in the frame memory 610. The threshold unit 620 compares the pixel value D with a reference value: if the pixel value D is larger than the reference value, a threshold value from the threshold unit 620 will be the first value; otherwise, it will be the second value.

[0070] Then, the calculation unit 630 outputs a compensation pixel value according to the pixel value D and the threshold value: if the threshold value is the second value, the compensation pixel value will be decided according to double of the pixel value D; otherwise, the compensation pixel value will be determined according to the result of double of the pixel value D minus the predetermined high pixel value.

[0071] The expand unit 640 receives the threshold value and outputs a precharge pixel value. If the threshold value is the first value, the precharge pixel value will be the predetermined high pixel value; otherwise, it will be the low pixel value. The field controller 650 controls the multiplexer 660 to output the precharge pixel value or the compensation pixel value according to the first synchronization signal Fsync. The field controller 650 decides the sequence of the precharge field and the compensation field.

[0072] Referring to FIG. 8, it shows the block diagram of an LCD driving apparatus according to a fourth embodiment of the present invention. The driving apparatus 700 includes a frame memory 710, a mathematic unit, and a field controller 750. The mathematic unit includes a threshold unit 720, a calculation unit 730, an expand unit 740, and a multiplexer 760. The LCD driving apparatus 700 receives the pixel value D and thereby the source driver 770 outputs the driving voltage Vd.

[0073] For example, consider the refresh rate of 60 Hz, for which 60 frames are displayed in each second. The pixel value D is inputted into the LCD driving apparatus 700 according to the pixel clock signal Cp. The LCD driving apparatus 700 outputs the driving voltage Vd according to the pixel clock signal Cp', whose frequency is double of the pixel clock signal Cp, because that one frame period is divided into the compensation field and the precharge field.

[0074] First, the LCD driving apparatus 700 receives the pixel value D, and saves the pixel value D in the frame memory 710. The frame memory 710 outputs the saved pixel value D and also the threshold value of the previous frame period. The threshold unit 720 compares the received pixel value D with a reference value. If the pixel value D is larger than the reference value, the threshold value from the threshold unit 720 will be the first value and be saved in the frame memory 710. Otherwise, it will be the second value.

[0075] The calculation unit 730 outputs a compensation pixel value according to the pixel value D and the threshold value of the previous frame period. When the pixel value is not larger than the reference value, the compensation pixel value is determined according to double of the pixel value D. Otherwise, the compensation voltage is determined according to the result of double of the pixel value D minus the predetermined high pixel value.

[0076] Then, The calculation unit 730 determines the over-driving tactic according to the threshold value of the previous frame period. When the threshold value of the previous frame period is the first value, the predetermined high pixel value is provided in the precharge field of the previous frame period. So, the over-driving tactic for increasing the responding speed is decreasing the compensation pixel value of the present frame period. When the threshold value of the previous frame period is the second value, the minimum pixel is provided in the precharge field of the previous frame period. So that, the over-driving tactic for increasing the responding speed is increasing the compensation driving voltage of the present frame period.

[0077] The expand unit 740 receives the threshold value and outputs a precharge pixel value. If the threshold value is the first value, the precharge pixel value will be the predetermined high pixel value. Otherwise, it will be the predetermined low pixel value. The field controller 750 controls the multiplexer 760 to output the precharge pixel value or the compensation pixel value according to the first synchronization signal Fsync.

[0078] Referring to FIG. 9, it shows the block diagram of an LCD driving apparatus according to a fifth embodiment of the present invention. The precharge field is prior to the compensation field in the fifth embodiment, as compared with the fourth embodiment. The driving apparatus 800 includes a frame memory 810, a mathematic unit, and a field controller 850. The mathematic unit includes a threshold unit 820, a calculation unit 830, an expand unit 840, and a multiplexer 860. The LCD driving apparatus 800 receives the pixel value D and outputs driving value Dv, and thereby the source driver 870 outputs a driving voltage Vd.

[0079] For example, consider the LCD having the refresh rate of 60 Hz, for which 60 frames are displayed in each second. The pixel value D is inputted into the LCD driving apparatus 800 according to the above pixel clock signal Cp. The LCD driving apparatus 800 outputs the driving voltage Vd according to the pixel clock signal Cp', whose frequency is double of the pixel clock signal Cp, because that one frame period is divided into a precharge field and a compensation field.

[0080] First, the driving apparatus 800 receives the pixel value D, and delivers the pixel value D to the calculation unit 830 and the threshold unit 820. The threshold unit 820 compares the received pixel value D with a reference value. If the pixel value D is larger than the reference value, a threshold value outputted from the threshold unit 820 will be the first value and be delivered to the calculation unit 830 and the frame memory 810. Otherwise, it will be the second value.

[0081] Then, the calculation unit 830 outputs a compensation driving voltage according to the pixel value D and the threshold value from the frame memory 810. When threshold value is the second value, the compensation pixel value is determined according to double of the pixel value D. Otherwise, the compensation pixel value is determined according to the result of double of the pixel value D minus the predetermined high pixel value.

[0082] Then, the calculation unit 830 determines the over-driving tactic according to the threshold value. When the threshold value is the first value, the predetermined high pixel value is provided in the precharge field. So, the over-driving tactic of increasing the responding speed for the liquid crystal molecule is decreasing the compensation pixel value of the present frame period. When the threshold value of the previous frame period is the second value, the predetermined low pixel value is provided in the precharge field. Therefore, the over-driving tactic for increasing the responding speed for the liquid crystal molecule is to increase the compensation pixel value of the present frame period.

[0083] Next, the calculation unit 830 saves the compensation pixel value into the frame memory 810. The frame memory 810 outputs the saved compensation pixel value to the multiplexer 860 and outputs the threshold value to the expand unit 840.

[0084] The expand unit 840 receives the threshold value and outputs a precharge pixel value according to the threshold value. If the threshold value is the first value, the precharge pixel value will be the predetermined high pixel value. Otherwise, it will be the low pixel value. The field controller 850 controls the multiplexer 860 to output the precharge pixel value or the compensation pixel value according to the first synchronization signal Fsync.

[0085] The frame memory of the second, third, fourth, and fifth embodiments of the present invention saves the pixels of the whole frame. The frequency of Vs signal and the Hs signal should be doubled in displaying of the two pixel

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values corresponding to the precharge field and the compensation field during one frame period. Therefore, the Vs' signal is two times the frequency of the Vs signal, and the Hs' signal is two times the frequency of the Hs signal. In the second, third, fourth, and fifth embodiments of the present invention, the pixel values of all pixels for the first field are displayed orderly during the period of the Vs' signal, which is $\frac{1}{120}$ second. Then, the pixel values of all pixels for the second field are displayed orderly during the next period of Vs' signal, which is $\frac{1}{120}$ second.

[0086] Referring to FIG. 10, it shows the block diagram of an LCD driving apparatus according to a sixth embodiment of the present invention. The LCD driving apparatus 900 includes a frame memory 910, a mathematic unit, and a field controller 950. The mathematic unit includes a threshold unit 920, a calculation unit 930, an expand unit 940, and a multiplexer 960. The LCD driving apparatus 900 receives the pixel value D and outputs a driving value, and thereby the source driver 970 outputs the driving voltage Vd.

[0087] For example, consider the LCD having the refresh rate of 60 Hz, for which 60 frames are displayed in each second. The pixel value D is inputted into the LCD driving apparatus 900 according to the pixel clock signal Cp. The LCD driving apparatus 900 outputs the driving voltage Vd according to the pixel clock signal Cp', whose frequency is double of the pixel clock signal Cp, because that one frame period is divided into a precharge field and a compensation field.

[0088] First, the LCD driving apparatus 900 receives the pixel value D, and delivers the pixel value D to the calculation unit 930 and the threshold unit 920. The threshold unit 920 compares the received pixel value D with a reference value. If the pixel value D is larger than the reference value, a threshold value outputted from the threshold unit 920 will be the first value and be delivered to the frame memory 910. Otherwise, it will be the second value. The frame memory 910 outputs the threshold value to the calculation unit 930 and the expand unit 940.

[0089] Then, the calculation unit 930 outputs a compensation driving voltage according to the pixel value D and the threshold value from the frame memory 910. When threshold value is the second value, the compensation pixel value is determined according to the double of the pixel value D. Otherwise, the compensation pixel value is determined according to the result of double of the pixel value D minus the predetermined high pixel value.

[0090] The expand unit 940 receives the threshold value and outputs a precharge pixel value according to the threshold value. If the threshold value is the first value, the precharge pixel value will be the predetermined high pixel value. Otherwise, it will be the predetermined low pixel value. The field controller 950 controls the multiplexer 860 to output the precharge pixel value or the compensation pixel value according to the first synchronization signal Fsync.

[0091] In the second, third, fourth, and fifth embodiment of the present invention, the pixels of whole image is saved by the frame memory. However, the threshold value of each pixel, only having one bit, is saved by the frame memory 910 according to the sixth embodiment. Therefore, the sixth embodiment could efficiently decrease the needed memory required by the LCD driving apparatus 900.

[0092] Another scanning method is needed in the sixth embodiment because the pixels of the all image are not saved by the frame memory 910 and each pixel is instantaneously processed for outputting. Referring to FIGS. 11A and 11B, they show the scanning process for the nth frame period according to the sixth embodiment. For example, consider the compensation field is prior to the precharge field. The frequency for the Hs' signal is the two times the frequency of the Hs signal. The frequency for the Vs' signal is same as the Vs signal.

[0093] The bit stream of the pixel values is inputted into the LCD driving apparatus according to the pixel clock signal Cp. The pixel values for one frame are inputted completely in $\frac{1}{60}$ second, and the pixels for one horizontal line are inputted completely in two cycles of the Hs' signal. In the sixth embodiment, the pixels are instantaneously processed and displayed due to the lacking of memory for saving the pixel values when the pixel values for one horizontal line are received. The frame is divided into an upper part and a lower part, which are respectively corresponding to the horizontal lines 1~300 and the horizontal lines 301~600.

[0094] FIG. 11A shows the scanning process while receiving the pixel values for the upper part of the nth frame, wherein the first cycle of the Hs' signal at the very beginning is Hs'(0). The pixel values for each horizontal line are inputted at the each even cycles, such as Hs'(0), Hs'(2), Hs'(4), and so on. At the Hs'(0), the pixel values of the 1st horizontal line are inputted, and the compensation pixel values $C_1(n)$ for the 1st horizontal line of the nth frame are displayed. The threshold values of each pixel for the first horizontal line are saved in the frame memory.

[0095] At the Hs'(1), the pixel values of the 2nd horizontal line for the upper part are not inputted yet, and so that the precharge pixel values P301 (n–1) corresponding to the pixels of the (n–1)th frame for the 301st line, the 1thc horizontal line for the lower part, is displayed. The precharge pixel values P301 (n–1) are decided according to the threshold value saved in the frame memory.

[0096] At the Hs'(2), the pixel values of the 2nd horizontal line for the upper part are inputted. The precharge pixel values C2(n) corresponding to each pixels of the 2nd horizontal line is displayed. The threshold values corresponding to each pixel values for the 2nd horizontal line are saved in the frame memory.

[0097] At the Hs'(3), the pixel values of the 3rd horizontal line for the upper part are not inputted yet. The precharge pixel values P302 (n–1) corresponding to the pixels of the (n–1)th frame for the 302nd horizontal line, the 2nd horizontal line for the lower part, is displayed. The precharge pixel values P302 (n–1) are decided according to the threshold value saved in the frame memory.

[0098] The followings are deduced by analogy. Until the Hs'(599), the precharge pixel values corresponding to the (n–1)th frame for the lower part and the precharge pixel values corresponding to the nth frame for the upper part have been displayed.

[0099] FIG. 11B shows the scanning process while receiving the pixel values for the lower part of the nth frame. At the Hs'(600), the pixel values of the 301st horizontal line are inputted, and the compensation pixel values $C301(n)$ for the

301st horizontal line are displayed. The threshold values of pixels for the 301st horizontal line are saved in the frame memory.

[0100] At the Hs'(601), the pixel values of the 302nd horizontal line for the lower part are not inputted yet. The precharge pixel values P1(n) corresponding to the pixels of the nth frame for the 1st line of the nth frame is displayed. The precharge pixel values P1(n) are decided according to the threshold value saved in the frame memory.

[0101] At the Hs'(602), the pixel values of the 302nd horizontal line are inputted. The precharge pixel values C302(n) corresponding to pixels of the 302nd horizontal line is displayed. The threshold values corresponding to pixels for the 302nd horizontal line are saved in the frame memory.

[0102] At the Hs'(603), the pixel values of the 303rd horizontal line are not inputted yet. The precharge pixel values P2(n) corresponding to the pixels of the nth frame for the 2nd horizontal line is displayed.

[0103] The followings are deduced by analogy. Until the Hs'(1199), the precharge pixel values corresponding to the lower part for the nth frame and the precharge pixel values corresponding to the upper part for the nth frame have been displayed. Therefore, one frame can be completely displayed in one period of Vs signal.

[0104] Referring to FIG. 12, it shows the driving voltage of the driving method for an LCD according to a seventh embodiment of the invention. The pixel values D in the frame periods T1, T2, and T3 are supposed to be respectively 30, 200, and 30. The precharge field is prior to the compensation field in this embodiment. The compensation pixel value and the precharge pixel value are further compensated for overdriving. The precharge pixel value is either a first pixel value or a second pixel value, for example 5 and 240 respectively. The compensation pixel value is calculated such that the lightness of the frame period is substantially the same with lightness driven by the pixel value in the conventional method. The average of the compensation pixel value and the precharge pixel value substantially equals to the pixel value in this embodiment.

[0105] First, calculate the precharge pixel values and the compensation pixel values of the frame periods by the method of the first embodiment. The pixel value of the frame period T1 is 30, being smaller than the reference value of 128, so the precharge pixel value of the precharge field P1 is the second pixel value, which is 5 in this embodiment. Hence, the compensation pixel value of the compensation field C1 is determined to be 55. The pixel value of the frame period T2 is 200, being larger than the reference value of 128, so the precharge pixel value of the precharge field P2 is the first pixel value, which is 240 in this embodiment. Hence, the compensation pixel value of the compensation field C2 is determined to be 160. The pixel value of the frame period T3 is 30, being smaller than the reference value of 128, so the precharge pixel value of the precharge field P3 is the second pixel value, which is 5 in this embodiment. Hence, the compensation pixel value of the compensation field C3 is determined to be 55.

[0106] Then, determine the overdrive compensation value. The pixel value of frame period T2 is 200, being larger than that of the previous frame period T1, so the precharge pixel value of the precharge field P2 is added an overdrive

compensation value A1 and the compensation pixel value of the compensation field C2 is added an overdrive compensation value A2 for increasing the response speed of the liquid crystal molecules. The overdrive compensation values A1 and A2 are respectively 10 and 2 for example.

[0107] The overdrive compensation values can be determined according to the pixel value of the current frame period and that of the previous frame period. A table can be established according to the characteristics of the LCD in order to look for the best overdrive compensation values.

[0108] In this embodiment, both the precharge pixel value and the compensation pixel value are overdrivingly compensated, or only one of them is overdrivingly compensated. In addition, the overdrive compensation values can be determined according to the pixel values of previous frame periods, previous precharge fields, or previous compensation fields.

[0109] Besides, the sequence of the precharge field and the compensation field can be dynamically swapped according to the pixel values of each fields, for example.

[0110] Referring to FIG. 13, it shows the block diagram of an LCD driving apparatus according to an eighth embodiment of the present invention. The driving apparatus 1000 includes a frame memory 1010, a mathematic unit, and a field controller 1050. The mathematic unit includes a overdrive compensation unit 1020, a temperature sensor 1023, a calculation and expand unit 1030, and a multiplexer 1060. The LCD driving apparatus 1000 receives a pixel value D and outputs driving value Dv, which is either the precharge pixel value or the compensation pixel value. Then, the source driver 1070 thereby outputs driving voltage Vd to drive the LCD.

[0111] The LCD driving apparatus 1000 receives the pixel value D, saves the pixel value D in the frame memory 1010. Then, the calculation and expand unit 1030 outputs a compensation pixel value and a precharge pixel value according to the pixel value D and the overdrive compensation value from the overdrive compensation unit 1020. The precharge pixel value and the compensation pixel value are saved to the frame memory 1010 to be used later by the overdrive compensation unit 1020 and by the calculation and expand unit 1030 to output to the multiplexer 1060. The overdrive compensation unit 1020 outputs the overdrive compensation value according to the pixel value D, the precharge pixel value, the compensation pixel value, or the temperature value outputted by the temperature sensor 1023. The temperature sensor 1023 is not the necessary element in this embodiment, but can enhance the performance of the overdrive compensation unit 1020.

[0112] The field controller 1050 controls the multiplexer 1060 to output the precharge pixel value or the compensation pixel value according to the second synchronization signal derived from the first synchronization signal Fsync.

[0113] Referring to FIG. 14, it shows the block diagram of an LCD driving apparatus according to a ninth embodiment of the present invention. The driving apparatus 1100 includes a frame memory 1110, a mathematic unit, and a field controller 1150. The mathematic unit includes a overdrive compensation unit 1122, a calculation and expand unit 1130, and a multiplexer 1160. The LCD driving apparatus 1100 receives a pixel value D and outputs driving value Dv,

which is either the precharge pixel value or the compensation pixel value. Then, the source driver **1170** thereby outputs driving voltage Vd to drive the LCD.

[0114] The LCD driving apparatus **1100** receives the pixel value D, saves the pixel value D in the frame memory **1110**. Then, the calculation and expand unit **1130** outputs a compensation pixel value and a precharge pixel value according to the pixel value D and the overdrive compensation value from the overdrive compensation unit **1122**. The precharge pixel value and the compensation pixel value are saved to the frame memory **1110** to be used later by the overdrive compensation unit **1122** and by the calculation and expand unit **1130** to output to the multiplexer **1160**. The field controller **1150** controls the multiplexer **1160** to output the precharge pixel value or the compensation pixel value according to the second synchronization signal derived from the first synchronization signal Fsync.

[0115] Referring to FIG. **15**, it shows the block diagram of an LCD driving apparatus according to a tenth embodiment of the present invention. The driving apparatus **1200** includes a frame memory **1210**, a mathematic unit, and a field controller **1250**. The mathematic unit includes a overdrive compensation unit **1220**, a calculation and expand unit **1230**, and a multiplexer **1260**. The LCD driving apparatus **1200** receives a pixel value D and outputs driving value Dv, which is either the precharge pixel value or the compensation pixel value. Then, the source driver **1270** thereby outputs driving voltage Vd to drive the LCD.

[0116] The LCD driving apparatus **1200** receives the pixel value D, saves the pixel value D in the frame memory **1210**. Then, the calculation and expand unit **1230** outputs a compensation pixel value and a precharge pixel value according to the pixel value D and the overdrive compensation value from the overdrive compensation unit **1220**. The field controller **1250** controls the multiplexer **1260** to output the precharge pixel value or the compensation pixel value according to the second synchronization signal derived from the first synchronization signal Fsync.

[0117] Referring to FIG. **16A**, it shows the block diagram of an LCD driving apparatus according to an eleventh embodiment of the present invention. The driving apparatus **1300** includes a frame memory **1310**, a mathematic unit, and a field controller **1350**. The mathematic unit includes a look up unit **1302** and a multiplexer **1360**. The LCD driving apparatus **1300** receives a pixel value D and outputs driving value Dv, which is either the precharge pixel value or the compensation pixel value. Then, the source driver **1370** thereby outputs driving voltage Vd to drive the LCD. The pixel value D can be saved in the frame memory **1310** to be used by the look up unit **1302** later.

[0118] FIG. **16B** shows the table used by the look up unit. The look up unit **1302** finds the corresponding precharge pixel value and compensation value in this table according to the pixel value. When the pixel value is four (4), for example, the precharge pixel value and the compensation pixel value are looked up to be 0 and 9 respectively such that the lightness of the frame period equals to the lightness if driven by the pixel value. The input and the output lightness of an LCD are not necessarily linear, and the content of the table can be adjusted according to the characteristics of the LCD.

[0119] Several driving methods using different sequence of a precharge field and a compensation field, which are decided according to the pixel value of each field, are described as follows.

[0120] According to one embodiment of the present invention, the LCD drives a pixel according to N pixel values corresponding to N frame periods, where N is a nonzero integer. For example, the N pixel values include an i-th pixel value, and the N frame periods include an i-th frame period, where i is an integer not greater than N. The i-th frame period is divided into a precharge field and a compensation field. The driving method according to the embodiment of the present invention includes the following steps. First, an i-th precharge pixel value is determined to be either a predetermined first pixel value or a predetermined second pixel value as a result of comparing with the i-th pixel value. Then, an i-th compensation pixel value is determined so that the overall grey level corresponding to the i-th pixel value is substantially the same as the average of the grey level corresponding to the i-th precharge pixel value and that corresponding to the i-th compensation pixel value. After that, the pixel is driven according to the i-th precharge pixel value during the precharge field and according to the i-th compensation pixel value during the compensation field. Specifically, the driving step includes: determining an i-th precharge driving voltage corresponding to the i-th precharge pixel value; determining an i-th compensation driving voltage according to the i-th compensation pixel value; driving the pixel according to the i-th precharge driving voltage during the precharge field; and driving the pixel according to the i-th compensation driving voltage during the compensation field.

[0121] At the driving step, the lightness of the pixel driven according to the i-th precharge pixel value and i-th the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the i-th pixel value. According to one embodiment of the present invention, the precharge field comes before the compensation field when the i-th precharge pixel value is larger than the i-th compensation pixel value, and the compensation field comes before the precharge field when the i-th compensation pixel value is larger than the i-th precharge pixel value.

[0122] For example, as shown in FIG. **17**, the compensation field C1 comes before the precharge field P1 when the compensation pixel value (60) of the compensation field C1 is larger than the precharge pixel value (0) of the precharge field P1. The precharge field P2 comes before the compensation field C2 when the precharge pixel value (255) of the precharge field P2 is larger than the compensation pixel value (145) of the compensation field C2.

[0123] In this example, the larger one of the precharge pixel value and the compensation pixel value in one frame period is displayed earlier. Therefore, the average voltage difference between two adjacent fields is larger, which further accelerate the average response speed of liquid crystal molecules. Besides, the displaying way using the driving method as shown in FIG. **17** is more similar to the impulse type displaying way, and therefore the quality of dynamic images is further improved.

[0124] Another example of sequence of the precharge field P and the compensation field C is shown in FIG. **18**. As compared with the method illustrated in FIG. **17**, the pre-

charge field comes before the compensation field when the i-th precharge pixel value is smaller than the i-th compensation pixel value, and the compensation field comes before the precharge field when the i-th compensation pixel value is smaller than the i-th precharge pixel value.

[0125] For example, as shown in FIG. **18**, the precharge field P1 comes before the compensation field C1 when the precharge pixel value zero (0) of the precharge field P1 is smaller than the compensation pixel value (60) of the compensation field C1. The compensation field C2 comes before the precharge field P2 when the compensation pixel value (145) of the compensation field C2 is smaller than the precharge pixel value (255) of the precharge field P2. The method as shown in FIG. **18** has the same advantage as the method shown in FIG. **17**.

[0126] While the invention has been described by way of example and in terms of the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. Rather, it is intended to cover various modifications and similar arrangements and procedures, and the scope of the appended claims therefore should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements and procedures.

What is claimed is:

1. A method for driving a liquid crystal display (LCD), the LCD being adapted to receive a pixel value and to drive a pixel of the LCD according to the pixel value during a frame period, the frame period being divided into a precharge field and a compensation field, the method comprising:

deciding a precharge pixel value to be either a predetermined first pixel value or a predetermined second pixel value according to the pixel value;

deciding a compensation pixel value; and

driving the pixel according to the precharge value and the compensation pixel value, comprising:

determining a precharge driving voltage corresponding to the precharge pixel value;

determining a compensation driving voltage corresponding to the compensation pixel value;

driving the pixel according to the precharge driving voltage during the precharge field; and

driving the pixel according to the compensation driving voltage during the compensation field;

wherein at the driving step, the lightness of the pixel driven according to the precharge pixel value and the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the pixel value;

wherein the precharge field comes before the compensation field when the precharge pixel value is larger than the compensation pixel value, and the compensation field comes before the precharge field when the compensation pixel value is larger than the precharge pixel value.

2. A method for driving a liquid crystal display (LCD), the LCD being adapted to receive a pixel value and to drive a pixel of the LCD according to the pixel value during a frame period, the frame period being divided into a precharge field and a compensation field, the method comprising:

deciding a precharge pixel value to be either a predetermined first pixel value or a predetermined second pixel value according to the pixel value;

deciding a compensation pixel value; and

driving the pixel according to the precharge value and the compensation pixel value, comprising:

determining a precharge driving voltage corresponding to the precharge pixel value;

determining a compensation driving voltage corresponding to the compensation pixel value;

driving the pixel according to the precharge driving voltage during the precharge field; and

driving the pixel according to the compensation driving voltage during the compensation field;

wherein at the driving step, the lightness of the pixel driven according to the precharge pixel value and the compensation pixel value is substantially the same as the lightness of the pixel if driven according to the pixel value;

wherein the precharge field comes before the compensation field when the precharge pixel value is smaller than the compensation pixel value, and the compensation field comes before the precharge field when the compensation pixel value is smaller than the precharge pixel value.

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摘要(译)

提供一种液晶显示（LCD）驱动方法。根据预充电像素值和补偿像素值驱动LCD的像素，所述预充电像素值和补偿像素值均分别在预充电场和补偿场期间从像素值生成。然后确定对应于预充电像素值的预充电驱动电压，以及对应于补偿像素值的补偿驱动电压，并用于驱动像素。如果根据像素值驱动，则根据预充电像素值和补偿像素值驱动的像素的亮度与像素的亮度基本相同。当预充电像素值大于补偿像素值时，预充电场到达补偿场之前，并且当补偿像素值大于预充电像素值时，补偿场到达预充电场之前。