

Novel Impulsive Driving Schemes for 120Hz LCD Panels

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Abstract

Two new impulsive driving technologies for 120Hz liquid crystal display (LCD) panels are proposed to improve moving picture quality. One technology generates the dark frame using an adder and a shifter simply without using any look up tables (LUTs). It results in a cost effective impulsive scheme with motion picture quality comparable to that of high speed driving. The other is a backlight flashing method designed to avoid ghost images. The issue of ghost images caused by the slow response time of liquid crystal (LC) is solved by means of 120Hz overdriving and 120Hz backlight flashing. Using the perceived blur edge time (PBET) metric, measured moving picture response time (MPRT) values were 10.8ms and 4.4ms, respectively, while that of 120Hz high speed driving was 10.1ms.

Keywords : LCD, Impulsive driving, Frame repeating, Backlight flashing, Ghost, MPRT, PBET

1. Introduction

Liquid crystal displays (LCDs), compared to CRT displays, have improved the features of display applications in terms of contrast, spatial resolution, brightness, size, weight, and power consumption. However, the moving picture quality of LCDs is still inferior to that of CRT displays due to blurring caused by the liquid crystal's (LC's) slow response time, LCD hold-type driving, and smooth eye tracking. The response time issue has been addressed well by means of over-driving technology [1][2] and high-speed LC material such as OCB [3]. On the other hand, in order to cope with motion blur caused by hold-type driving and smooth eye tracking, a great deal of recent research has focused on high speed driving or CRT-like impulsive driving [4][5][6]. While the high-speed driving method can reduce motion blur without any side effects, a large amount of hardware is required to implement the motion estimation/ motion compensation (ME/MC) algorithm. If the algorithm generates some errors on particular patterns, those artifacts will be shown directly on the display. Therefore, many LCD panel makers consider impulsive driving technologies as a cost-effective solution compared to high speed driving technology, even though impulsive driving technology causes loss of brightness and large area flicker. Fig. 1 explains the technologies developed to improve motion picture quality.

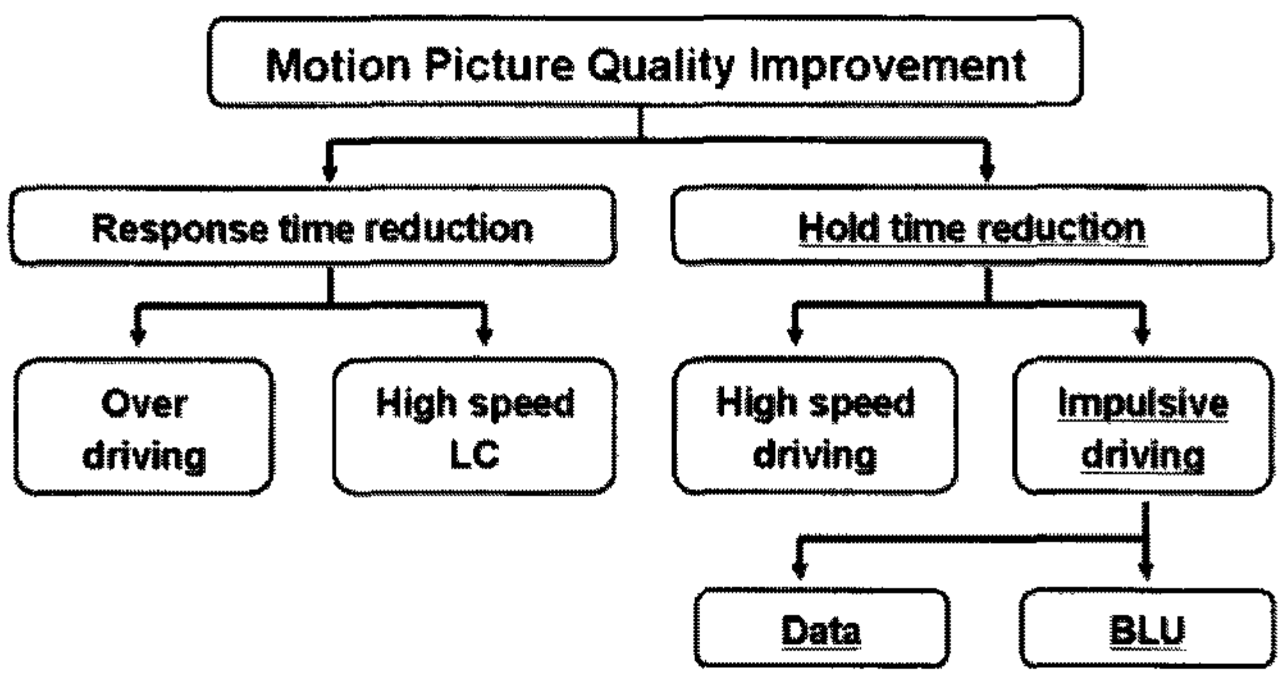

Fig. 1. Technologies for improvement of motion picture quality.

2. Impulsive Driving Technologies

The key concept of impulsive driving technology on LCDs is to add a dark frame between input frames. Since the brightness of LCDs can be controlled by data or by the backlight, a dark frame can be generated either by way of image data manipulation or by dynamic backlight control as shown in Fig. 2. The data manipulation method enables a dark frame to be formed by changing the frame data into

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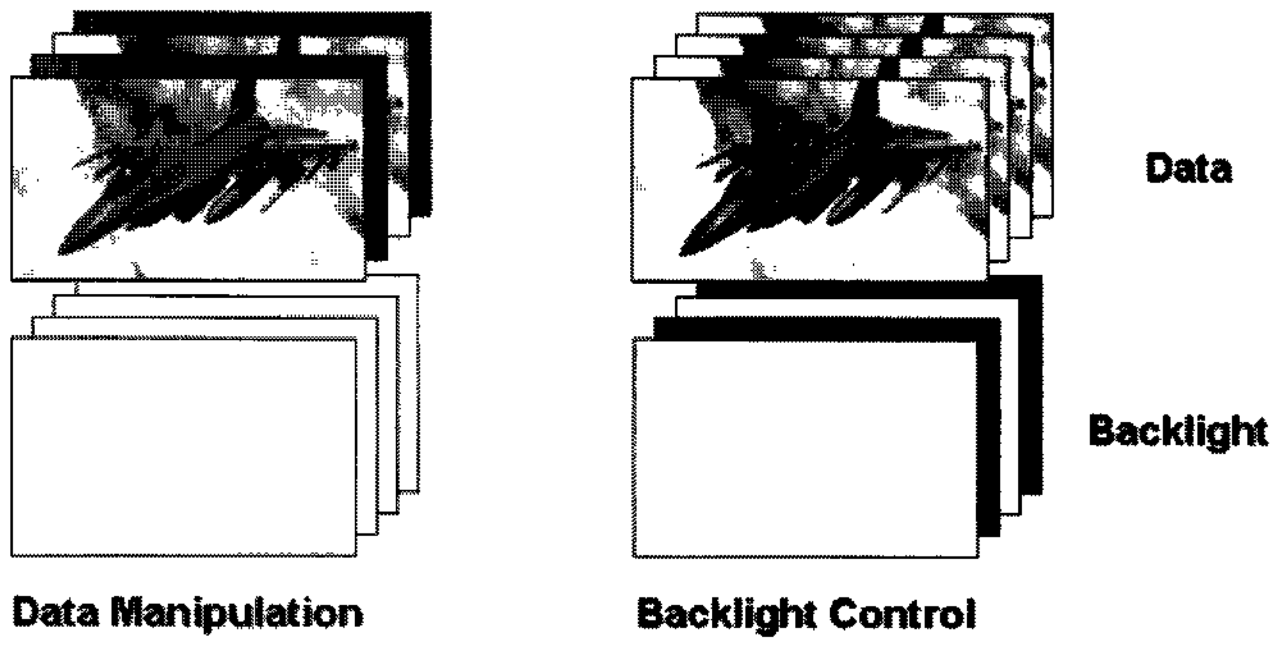


Fig. 2. Impulsive driving technologies.

dark grays. The dynamic backlight method generates a dark frame by turning off the backlight.

2.1 Super Impulsive Driving: data manipulation method

Up to now, there have been two impulsive schemes using data manipulation, which are classified as black frame insertion and quasi-impulsive driving. As shown in Table 1, black frame insertion (BFI) has the disadvantage of 50% brightness loss, while the quasi-impulsive driving (QID) method can not improve MPRT at the high grays. Moreover, it requires dedicated LUTs. Since there are cases for which the desired luminance can not be achieved, both technologies generate some artifacts on the display such as ghost images, color shifts, and so forth. BFI is just like CRT driving, but because the LC response time is not fast enough to get to the desired black level within one frame time, some artifacts appear in the display. QID was proposed to resolve these problems of BFI by reducing the transition swing. QID generates the dark frame using a look-up table which has the mapping information. However, if the bit depth of the input is larger, the LUT size increases dramatically Moreover, since existing QID methods use only current frame data, they cannot take into consideration the transition swings between light and dark frames.

Table 1. Comparison of existing impulsive driving schemes

	BFI	QID
Brightness	50% loss	No loss
MPRT improvement	At all gray levels	No improvement at high gray levels
Look up table	Not necessary	Necessary
Artifact from slow LCD response time	Artifacts	Artifacts

Therefore, the proposed scheme, super impulsive driving (SID), is suggested, and is intended to reduce brightness loss, improving motion pictures at all gray levels, eliminating the need for a LUT, and having less artifacts from slow LC response time. To address them, dark image generation at all gray levels is adopted with gray insertion using simple arithmetic logic of previous and current frame data. As described in Fig. 3, the 60Hz input frame is repeated at 120Hz and the first of those repeated frames becomes a dark frame using simple logic. To minimize the hardware requirement, the dark frame is generated using an adder and a shifter without any LUTs as shown in Fig. 4. Concerning the transition swings between light and dark frames, this algorithm uses previous and current frame data, and is defined as

$$G_{120Hz}(n) = \frac{G_{60Hz}(n-1) + G_{60Hz}(n)}{4}$$
$$G_{120Hz}\left(n+\frac{1}{2}\right) = G_{60Hz}(n) \quad \text{(Eq. 1)}$$

where n is the frame index at 60Hz operation. If the darker frame is needed, a denominator that is greater than 4 can be used in Eq. 1. However, the larger the denominator is,

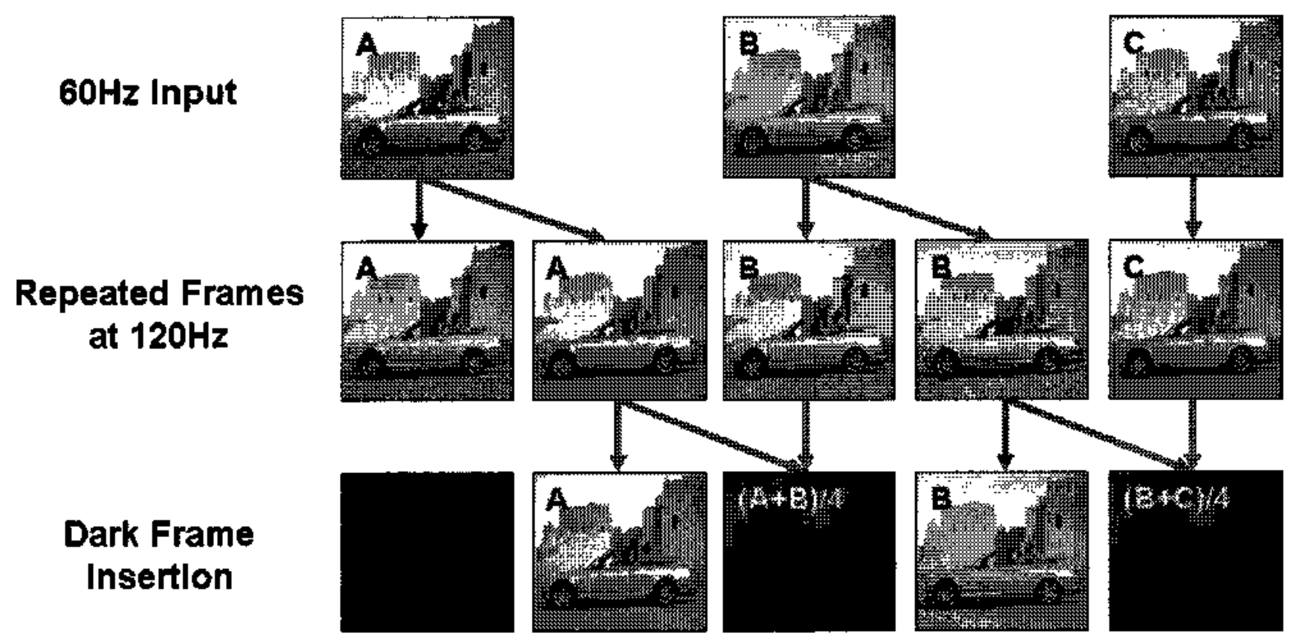


Fig. 3. Frame sequence of super impulsive driving scheme.

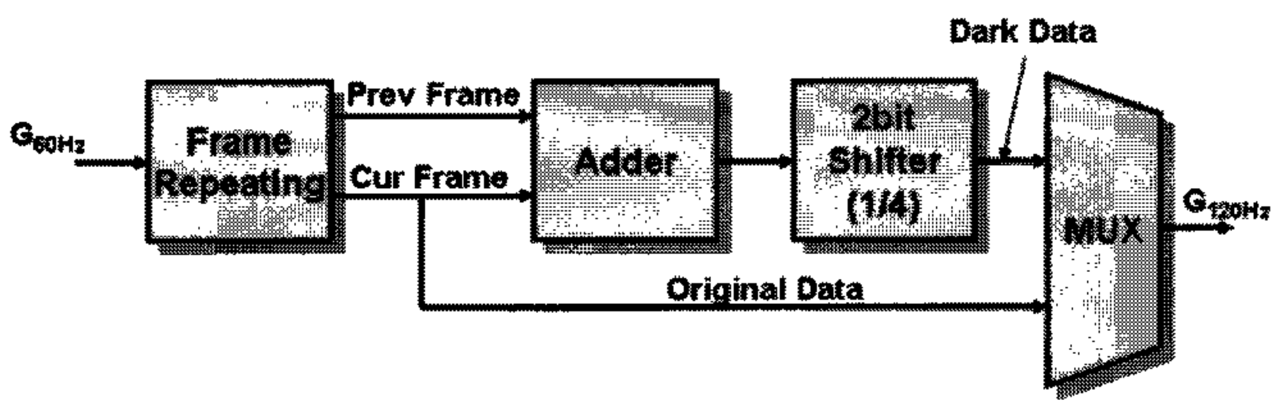


Fig. 4. Block diagram of dark frame generation.

the more severe the artifact is from the slower the response time of LC. Thus, in order to use a simple shifter, the denominator should be 2^n. Therefore, SID adopted 4, showing the comparable MPRT performance to that of 120Hz display.

The frame repeating block is implemented by reading the data from the memory at double the frame rate. Fig. 5 explains how the memory is accessed to generate rate-doubled frame streams using two DDR memories. Two external DDR memories are adopted to store the even and odd frame data. Because one write and two read operations per pixel should be supported by DDR memories using both rising and falling edges, the memory clock frequency is 1.5 times the input pixel clock frequency. Fig. 6 shows the architecture of the impulsive driving TCON. A 60Hz frame input is stored in external DDR memories, and then the TCON reads the frame data of DDR memories at 120Hz, repeating 60Hz frame data. The dark frame generation block changes the first one of the two repeated 120Hz frames into a dark frame and is followed by accurate color capture (ACC) and dynamic capacitance compensation (DCC) which are color correction and overdriving blocks respectively.

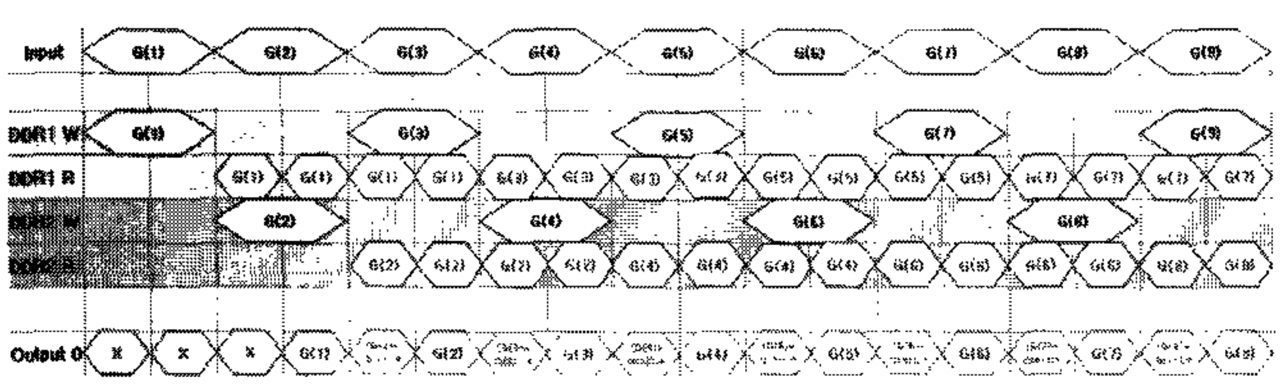


Fig. 5. Timing diagram of memory interface.

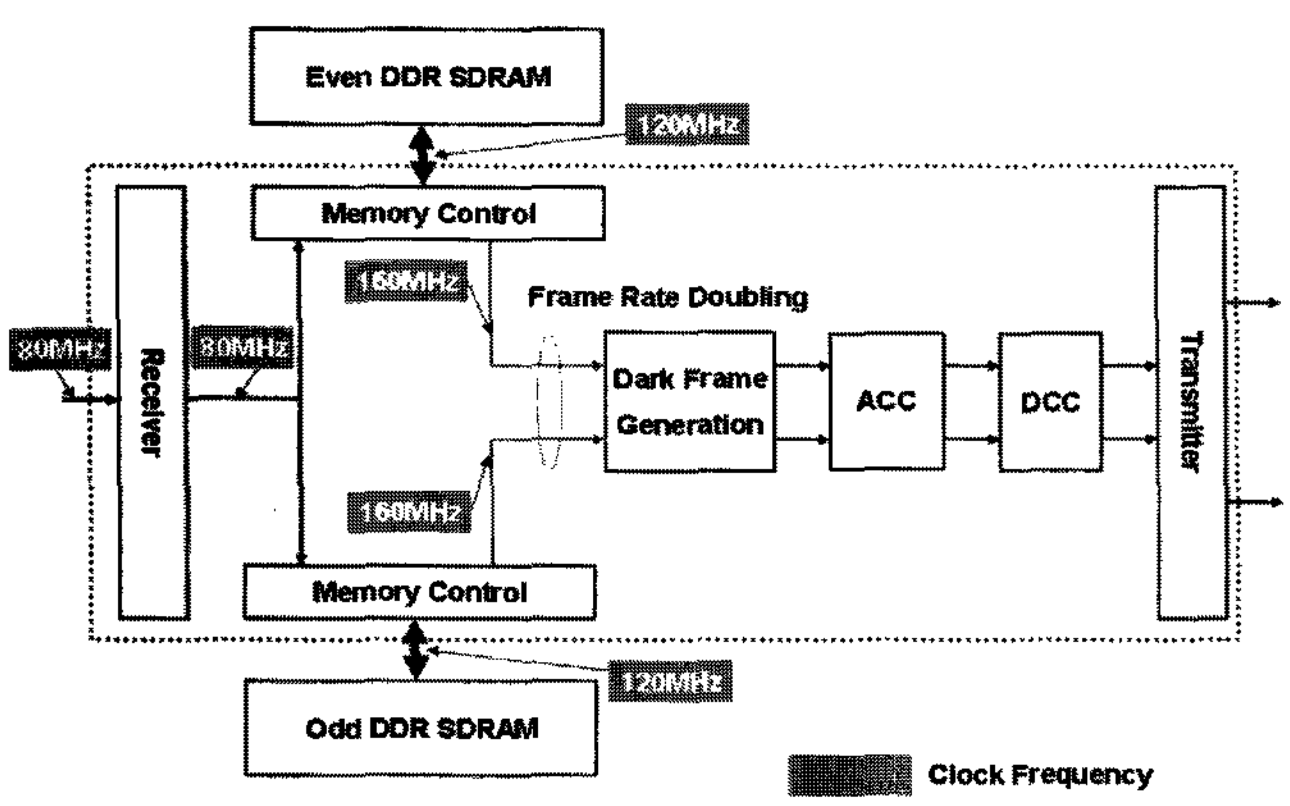
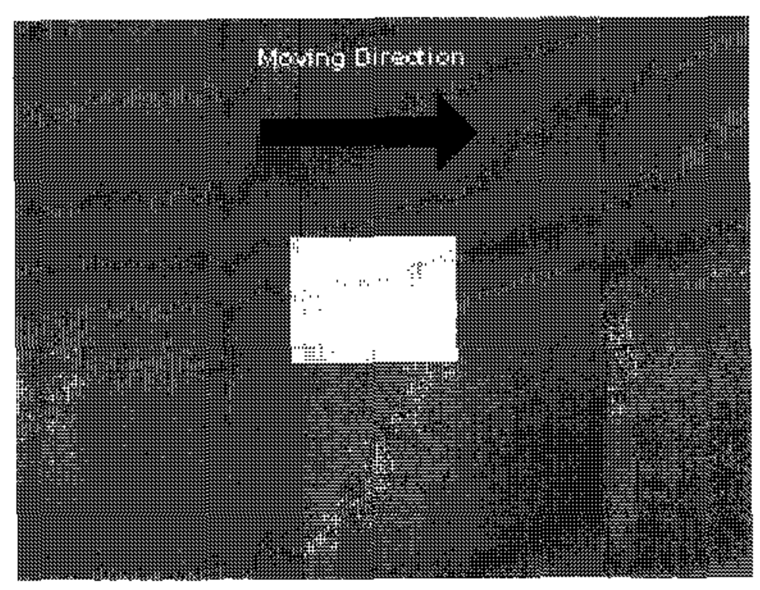


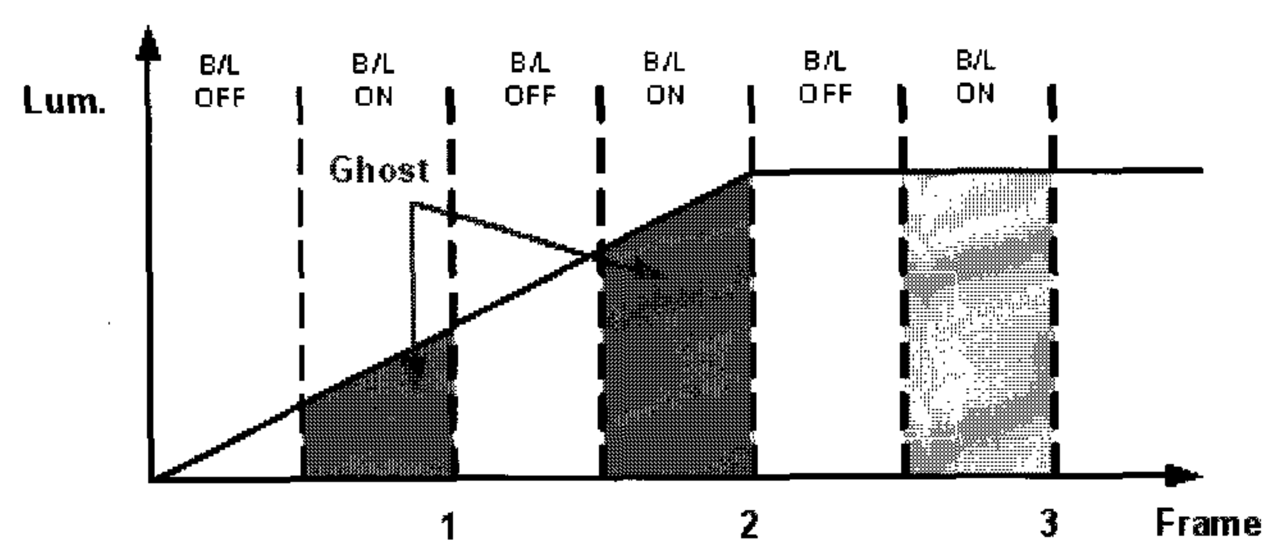
Fig. 6. Architecture of impulsive driving TCON.

2.2 Ghost Elimination: backlight flashing

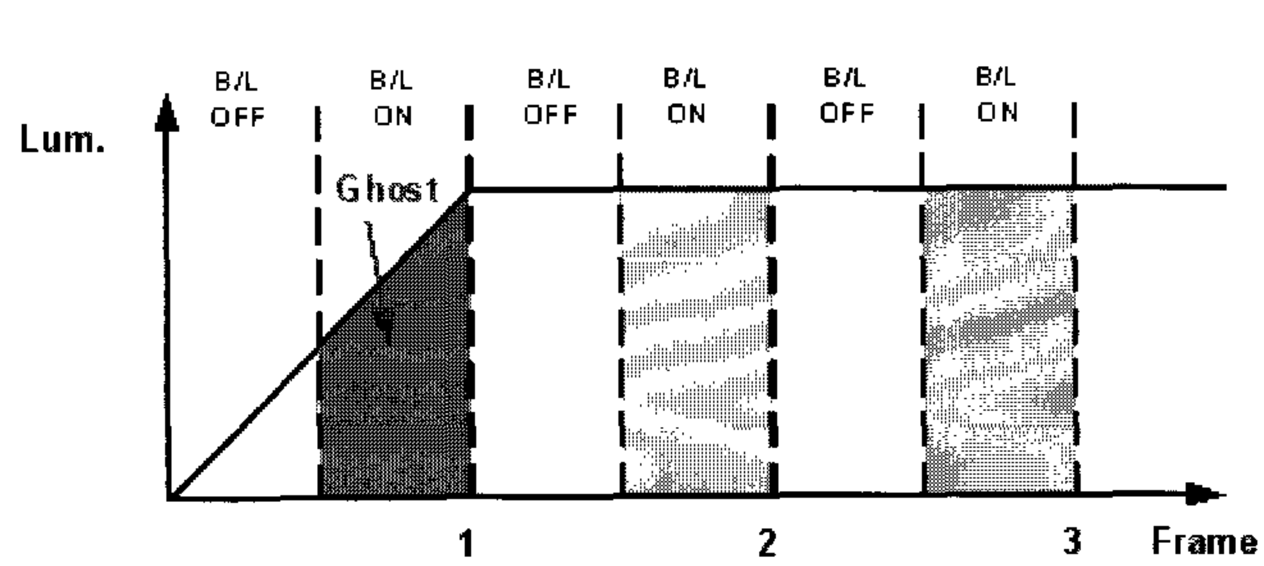
It is possible for an LCD to become an impulsive display by flashing its backlight [7]. This scheme can generate dark frames regardless of the LCD's response time. The dark frame can be obtained just by turning off the backlight. However, this scheme can create a ghost artifact which results due to slow response characteristics of the LCD. With the approximation of the response curve as linear, the ghost phenomenon can be explained as shown in Fig. 7. Fig. 7(a) shows the test pattern, which is a light box scrolled across a dark background. Fig. 7(b) shows that with no overdrive, there can be two ghosts because of the time required for the LCD to achieve target luminance. If the response time is shortened using overdrive, the ghost effect is reduced, but one ghost image can still occur as shown in Fig. 7(c).



(a) Test pattern: scrolling box



(b) Backlight flashing without over-drive



(c) Backlight flashing with over-drive

Fig. 7. Backlight flashing ghost phenomenon.

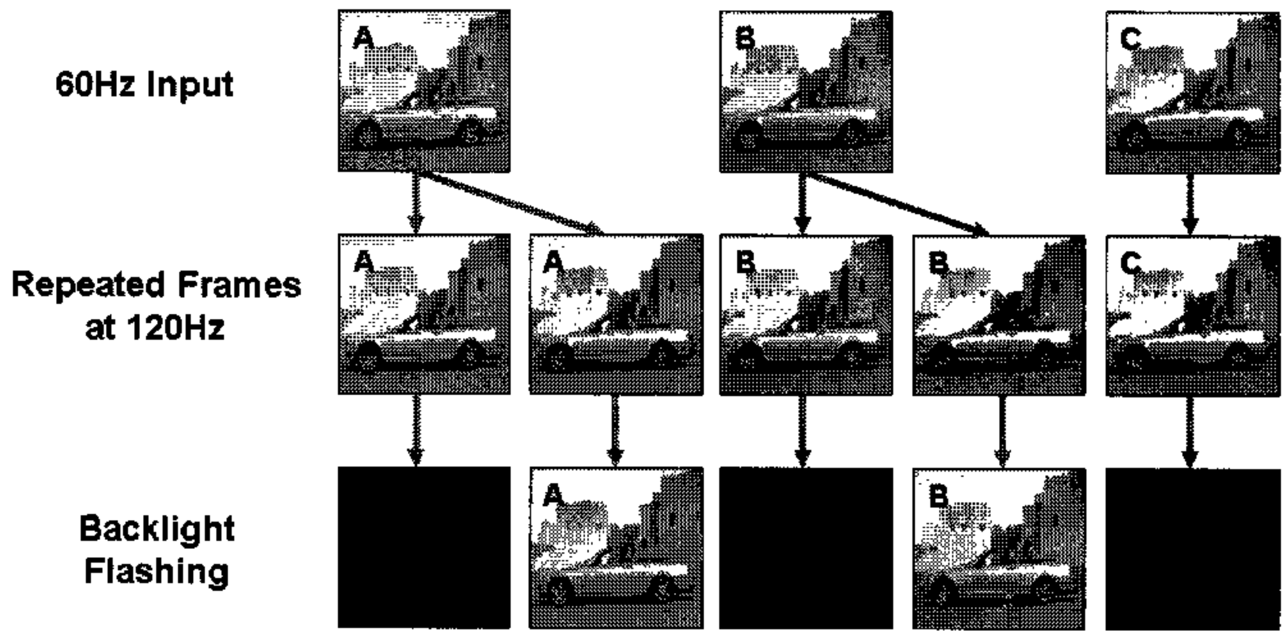


Fig. 8. Frame sequence of ghost elimination scheme.

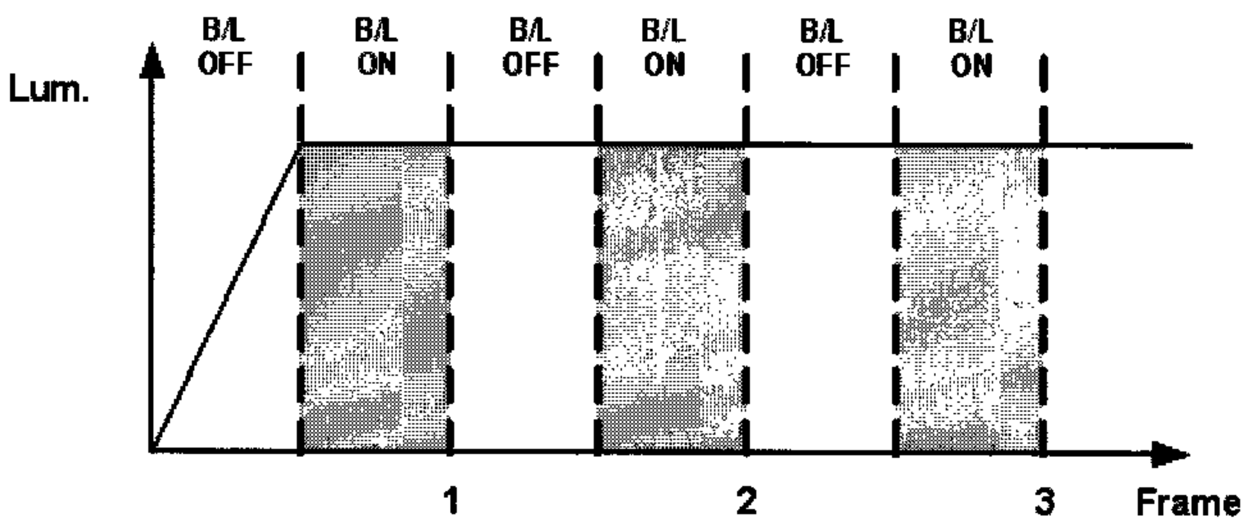


Fig. 9. Response curve of ghost-free backlight flashing.

In order to eliminate the ghost, the LCD must settle at the target before the backlight is turned on. This means that the response time should be much less than one frame time, which would imply the need for another type of high speed LC such as OCB. However, in this paper, we propose a novel implementation method using the existing LCD to achieve the desired curve.

As explained in Fig. 8, the method works as follows: First, the 120Hz frame rate doubled images are generated from the frame repeating block. Then, high speed (120Hz) over-drive achieves the desired response time, which is half of the 60Hz frame time. The backlight flashing is applied at the second sub-frame so that the LC transition occurs during the dark period. As a result, the ghost is completely removed as shown in Fig. 9.

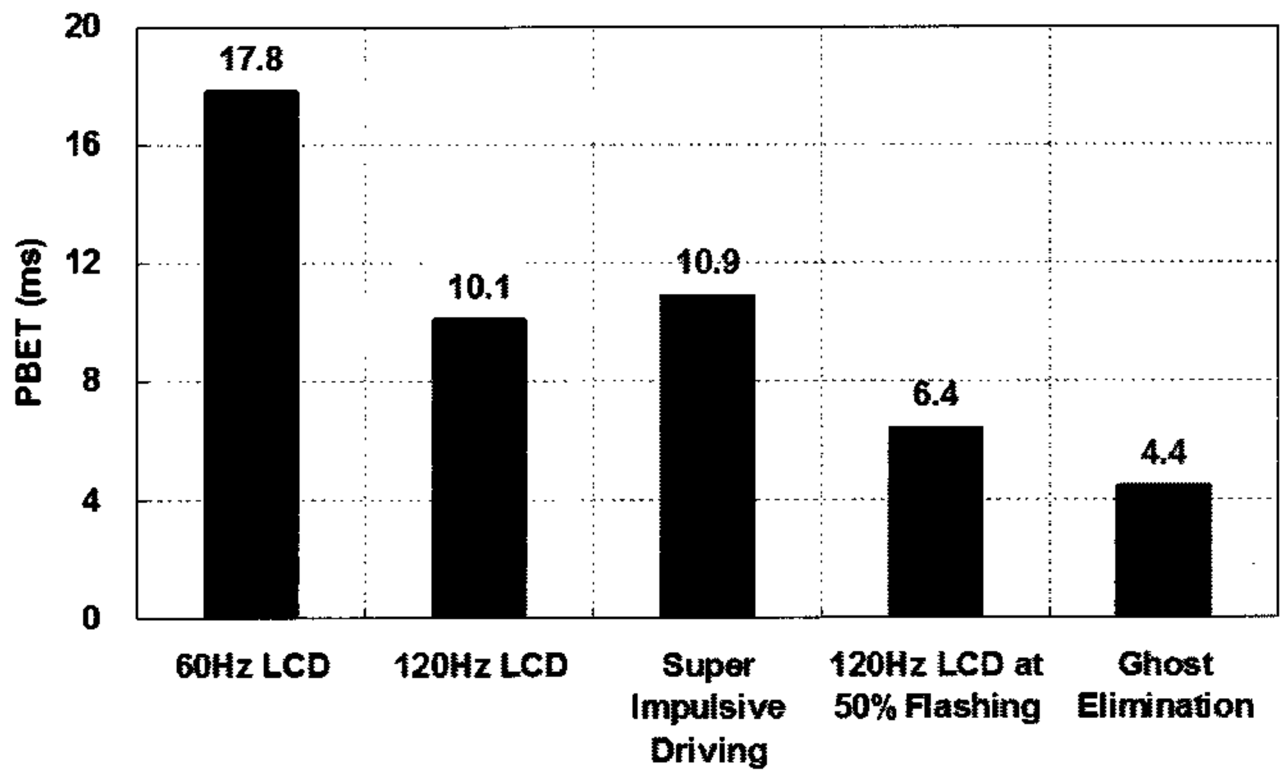


Fig. 10. MPRT measurement.

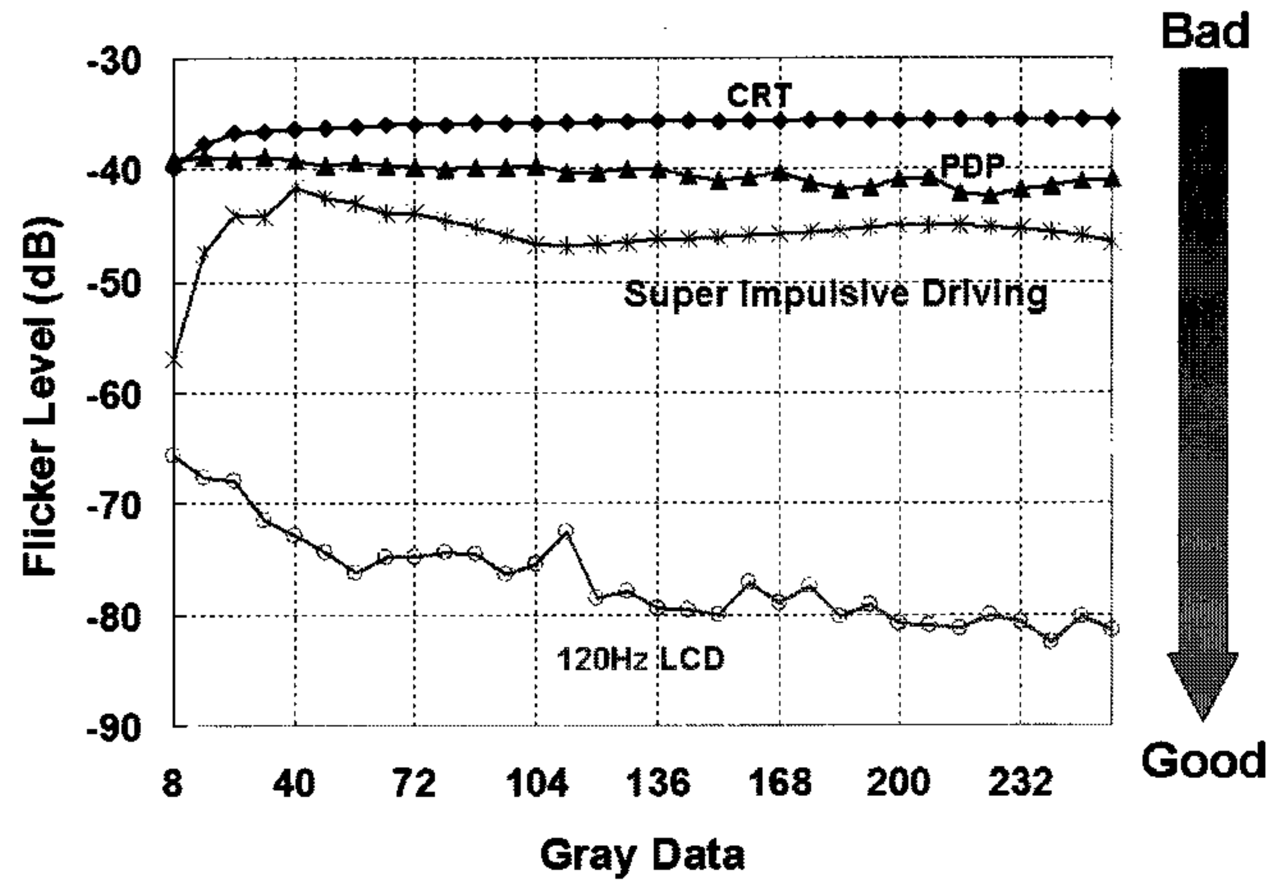


Fig. 11. Flicker characteristics.

3. Measurement

The proposed method has been implemented on a 120Hz 40" WXGA (1366x768) S-PVA panel. As a metric of moving picture response time (MPRT), the perceived blur edge time (PBET) [8] was measured with an MPRT-1000. The MPRT performance of SID was compared with 60Hz, and 120Hz displays. The ghost elimination scheme used a backlight of 75% black insertion at 60Hz frame rate and was compared with the display of 50% black insertion at 120Hz frame rate, achieving equal hold time for both cases. Fig. 10 shows that SID's performance is similar to that of a 120Hz display and the ghost elimination scheme is better than the 120Hz display with 50% black insertion even at the same hold time.

To check the side effects of the impulsive driving methods, flicker and brightness of SID were measured and the results are shown in Fig. 11 and Fig. 12. For flicker, the JEITA method was used with a solid pattern for each gray level. With respect to brightness, the white brightness was measured using a solid white pattern. SID has about 25% loss of white brightness and severe large area flicker when compared with a 120Hz display. All the impulsive driving methods have a large area flicker because there is a transition between light and black grays at every frame, resulting in luminance fluctuation at half the frame rate. However, SID displays less severe flicker than that of BFI displays like PDP and CRT because the amplitude of the luminance fluctuation is smaller.

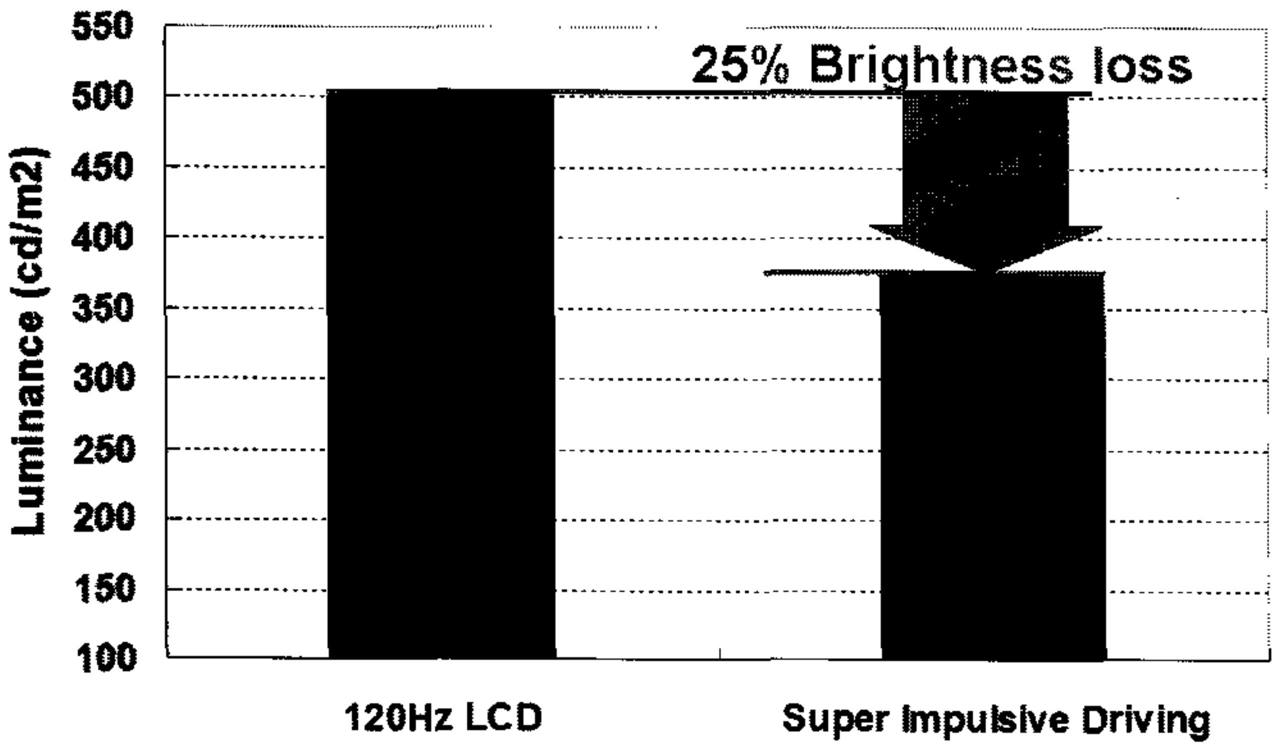


Fig. 12. Brightness characteristics.

4. Conclusions

This paper proposes two impulsive driving methods to address the LCD motion blur problem. One method is a low cost solution which uses data manipulation by adopting an adder and a shifter instead of LUTs. The other is a simple solution to eliminate the ghost effect which can occur when using the backlight flashing method. Both methods use frame rate doubling with a 120Hz panel. In this study, we successfully obtained outstanding MPRT performance of 10.9ms and 4.4ms, respectively, through the two impulsive driving methods. Side effects of the impulsive driving methods, including large area flicker and brightness loss, were examined. To apply the impulsive driving methods to real products, effective countermeasures for these side effects need to be developed.

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