Novel Impulsive Driving Schemes for 120Hz LCD Panels

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Abstract

Two new impulsive driving technologies for use in 120Hz 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 LUTs. The other is a backlight flashing method designed to avoid ghost images. Using the PBET metric, measured MPRT values were 10.8ms and 4.4ms, respectively.

1. Introduction

Liquid crystal displays (LCDs) have brought many advantages to display applications with respect to contrast, spatial resolution, brightness, size, weight, and power consumption, compared to CRT displays. However, the moving picture quality of LCDs is still poorer than that of CRT displays due to blurring caused by liquid crystal's (LC's) slow response, hold-type driving, and smooth eye tracking. The response time issue has been addressed well by means of an over-drive technology [1][2] and a high-speed LC such as OCB [3]. On the other hand, in order to cope with the motion blur caused by hold-type driving and smooth eye tracking, much 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, it needs large hardware 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 have studied 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. Impulsive driving technologies can be classified into two categories: data manipulation and dynamic backlight. This paper proposes new impulsive driving methods using a 120Hz LCD panel for the two respective categories.

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. The data manipulation method achieves a dark frame by changing the frame data into dark grays. The dynamic backlight method generates a dark frame by turning off the backlight.

2.1 Impulsive 1: data manipulation method

The impulsive driving scheme of the image data manipulation method consists of a frame rate doubling (FRD) block and a dark frame generation block as shown in Fig. 1.

The FRD block divides the 60Hz frame into two 120Hz sub-frames, and the dark frame generation block changes the data of one sub-frame to the lower gray level to achieve an impulsive effect. If the dark frame is at black level, this method is referred to as black frame insertion (BFI), and if it is at a gray level, it is referred to as gray frame insertion (GFI). BFI is just like CRT driving, but because the response time is not fast enough to get to the desired black level within one frame time, some artifacts appear in the display. GFI was proposed to improve upon the problems of BFI by reducing the transition swing time. GFI generates the dark frame using a look-up table (LUT) which has the mapping information. However, if the bit depth of the input is larger, the LUT size increases dramatically. Moreover, since existing GFI methods use only current frame data, they cannot provide a means to take into consideration the transition swings between light and dark frames.

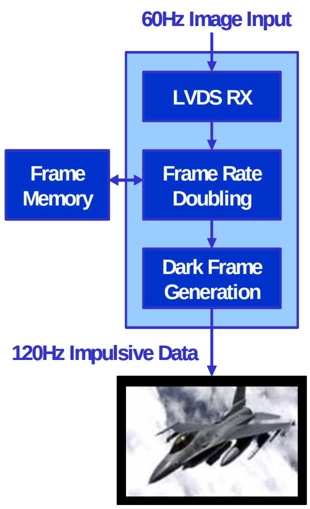


Fig.1. Block diagram of the proposed data manipulation method

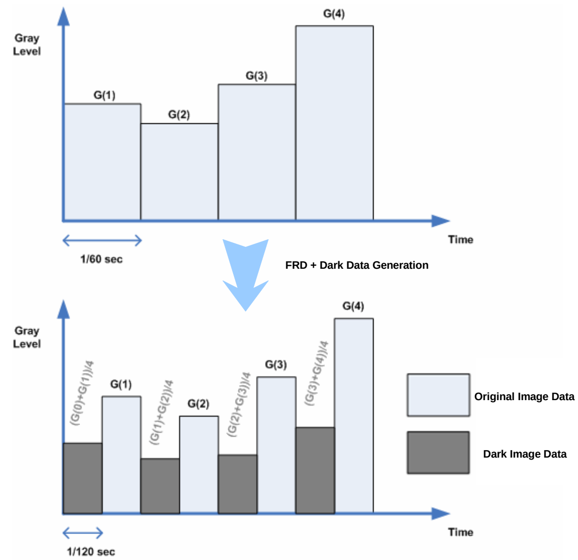


Fig.2. Concept of the dark image generation

To overcome these drawbacks of the BFI and GFI methods, we developed a new impulsive algorithm. To minimize the hardware requirement, the dark frame is generated using an adder and a shifter without any LUTs. Concerning the transition swings between light and dark frames, this algorithm uses previous and current frame data, and is defined as

$$G_{120Hz}(n) = \frac{G_{60Hz}(n-1) + G_{60Hz}(n)}{4}$$

$$G_{120Hz}\left(n+\frac{1}{2}\right) = G_{60Hz}(n) \qquad (1)$$

where n is the frame index at 60Hz operation.

Fig. 2 illustrates the concept of the dark frame generation. First, the internal frame rate is doubled after the FRD block, which causes the input frame to be repeated. The input frame stream, {G(1), G(2), G(3), …} is changed into {G(1), G(1), G(2), G(2), G(3), G(3), …}. Then, the dark frame generation block substitutes the first frame among two repeated frames with the dark frame given by the equation (1). According to the equation (1), the dark frame generation block needs another rate-doubled frame stream with one frame delay based on 60Hz frame time, {G(0), G(0), G(1), G(1), G(2), G(2), …}. The final frame stream becomes {(G(0)+G(1))/4, G(1), (G(1)+G(2))/4, G(2), (G(2)+G(3))/4, G(3), …}.

The FRD block is implemented by reading the data from the memory at double the frame rate. Fig. 3 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 a pixel data should be supported by DDR memories using both rising and falling edges, the memory clock frequency becomes 1.5 times the input pixel clock frequency. Fig. 4 shows the architecture of the impulsive driving TCON.

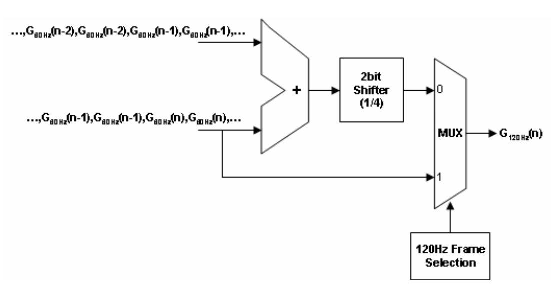


Fig.3. Architecture of a dark frame generation

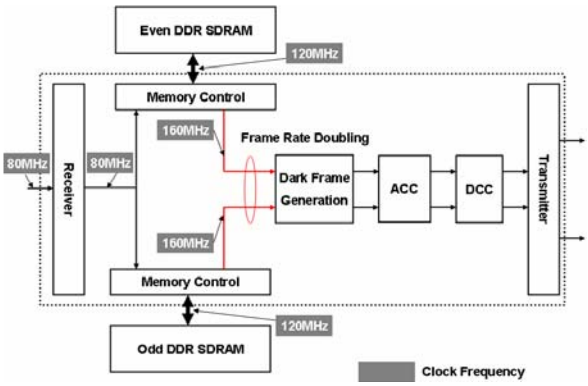
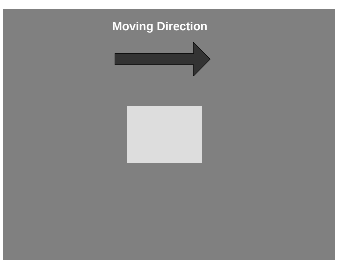
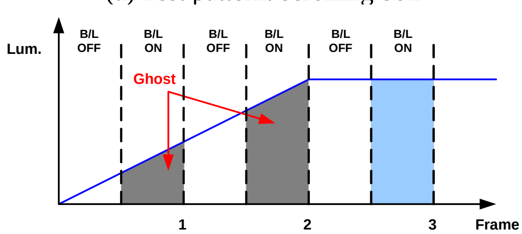


Fig.4. Architecture of impulsive driving TCON

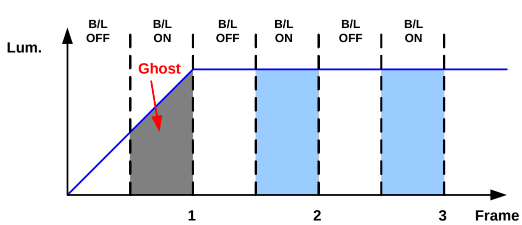
2.2 Impulsive 2: backlight flashing



(a) Test pattern: scrolling box



(b) Backlight flashing without over-drive



(c) Backlight flashing with over-drive

Fig.5. Backlight flashing ghost phenomenon

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. 5. Fig. 5(a) shows the test pattern, which is a light box scrolled across a dark background. Fig. 5 (b) shows that with no overdrive, there can be two ghosts because of the time required for the LCD to achieve target luminance. If we shorten the response time using overdrive, the ghost effect is reduced, but one ghost image can still occur as shown in Fig. 5 (c).

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. The system architecture consists of an FRD block, a flashing backlight, and a 120Hz panel.

The method works as follows: First, the 120Hz frame rate doubled images are generated from the FRD 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. 6.

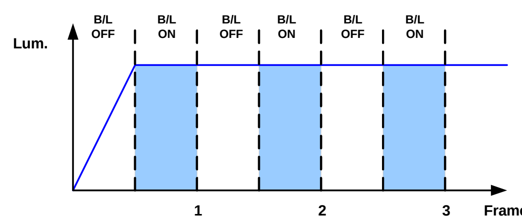


Fig.6. Response curve of ghost free backlight flashing

3. Measurement

A 120Hz 40inch HD Super-PVA panel was used as the test vehicle, and as a metric of moving picture response time (MPRT), perceived blur edge time (PBET) [8] was measured with an MPRT-1000. The MPRT performance of Impulsive 1 is compared with 60Hz and 120Hz displays at Table 1. Impulsive 1 has the MPRT value close to that of a 120Hz display.

TABLE 1. MPRT comparison for Impulsive 1

MPRT	PBET
60Hz	18ms
120Hz	10.1ms
Impulsive 1	10.8ms

For Impulsive 2, a LED backlight was used as a dynamic backlight and the duty ratio of backlight flashing was 25% based on a 60Hz frame time. To see the effect of a ghost on the PBET value, a 120Hz display with a backlight flashing was also measured. The backlight had the duty ratio of 50% based on 120Hz frame time, which is the same hold time as the duty ratio of 25% based on 60Hz frame time. Table 2 shows that Impulsive 2 outperforms a 120Hz display at the same hold time.

TABLE 2. MPRT comparison for Impulsive 2

MPRT	PBET
120Hz with a backlight flashing	6.4ms
Impulsive 2	4.4ms

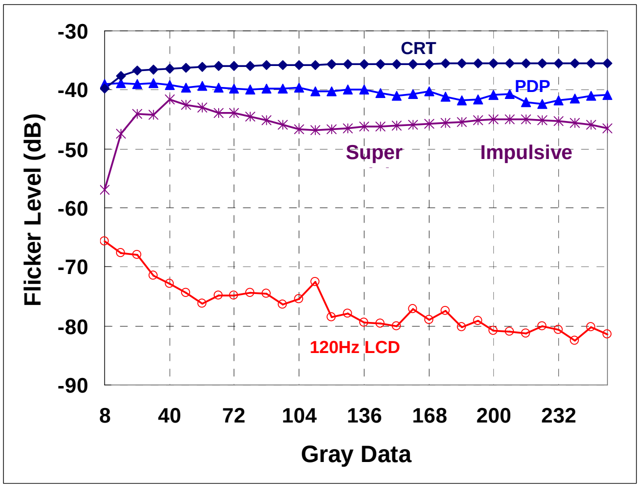


Fig.7. Flicker comparison

To check the side effects of the impulsive driving methods, flicker was measured and the results are shown in Fig. 7. The JEITA method was used to measure flicker levels with each gray data. With respect to the loss of brightness, the white brightness was measured at the white solid pattern. Impulsive 1 has about 25% loss of white brightness and severe large area flicker, compared with a 120Hz display. Impulsive 2 with 25% duty ratio of backlight flashing shows about 75% loss of white brightness.

4. Summary

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. By means of the two impulsive driving methods, outstanding MPRT performance was obtained. 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.

5. References

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