P-148: Motion Blur Reduction in LCDs

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Abstract

LCDs show motion image blur due to slow response time and a hold-type driving method. In this paper, we investigate motion blur phenomena and quantitatively show that the motion blur can be significantly reduced through a combination of dynamic capacitance compensation (DCC) and black data insertion.

1. Introduction

LCDs are now widely considered to have many advantages over other display types such as CRTs for resolution, power consumption, size, thickness, and other critical parameters. However, LCDs have a drawback for TV applications, namely motion blur which results from slow response time of liquid crystals and the inherent hold-type driving method [1-4]. CRT displays with short persistence phosphor are impulsively driven and do not produce motion blur. However hold-type displays, such as LCDs, sustain the image over the frame time, contributing to motion blur. One might overcome this problem by using black frame insertion between the image frames to realize CRT-like impulsive driving [1].

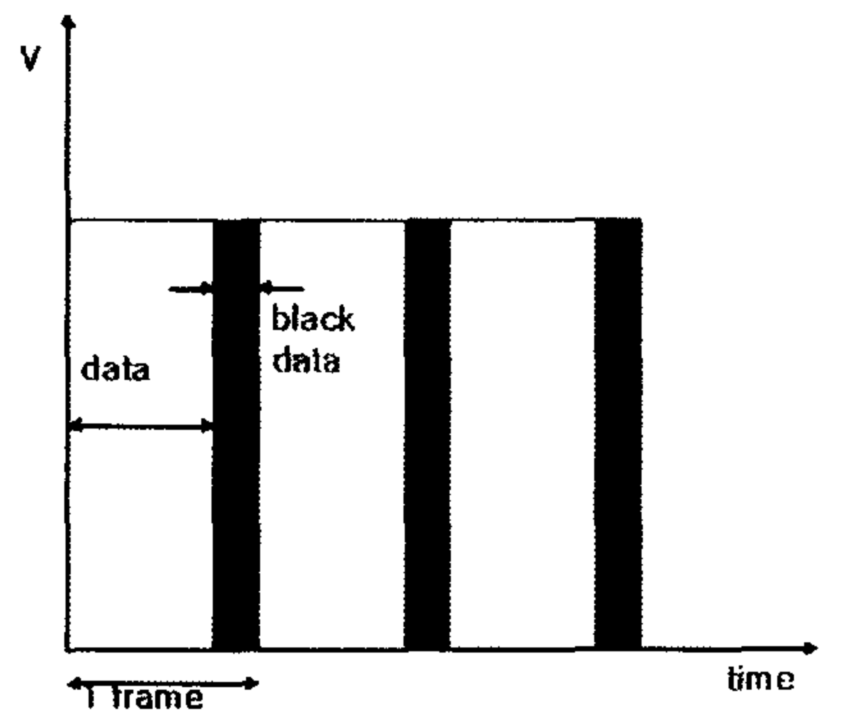
We have applied impulsive driving to LCDs using black data insertion at various moving picture speeds. In this approach, a black data is inserted between data frames from 0 % to 50 % of the full frame rate. The ratio of black data to active frames is critical. Insertion of more black data can offer better motion performance, but will also lower the contrast ratio (CR) of the LCD. Therefore there is a trade-off between the black frame insertion rate and the contrast ratio

Dynamic capacitance compensation (DCC) was also introduced to overcome slow response time in LCDs [5]. DCC can boost the response time by a factor of 2 ~3 times for gray to gray transitions. In this paper, we evaluate motion blur in LCDs at various image speeds and show that motion image blur can be significantly decreased through a combination of DCC and impulsive driving. We also show that proper selection of black insertion ratio can optimize the display's performance.

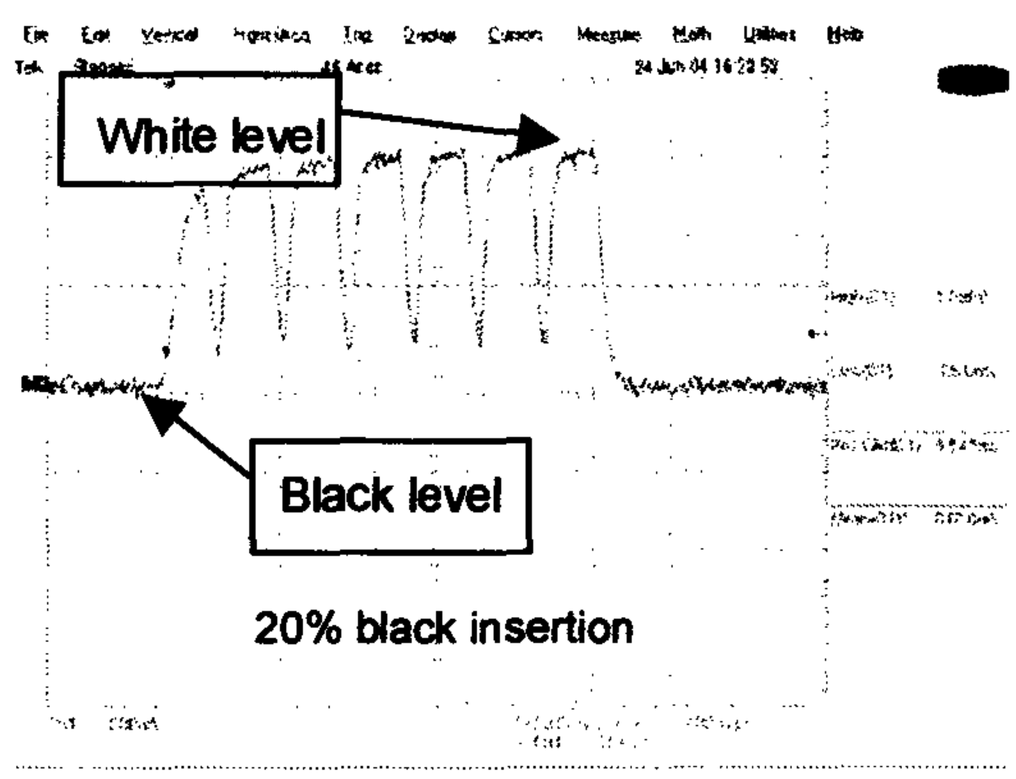
2. Experimental Setup

For the black frame insertion we have inserted black data within a frame with different black ratio as shown in Fig. 1. Figure 1 (b) shows the luminance output when 20 % of data frame is replaced by black data. We have changed the black insertion ratio from 0 % to 50 %. For 50 % black frame insertion, the data is displayed only half of the frame time, which is 1/120 second.

Figure 2 shows the experimental setup. An image with various speeds is sent to an LCD through the DCC board. The panel used was a patterned vertically aligned (PVA) 32" LCD. Image speed can be controlled with a computer and the output images were taken with a CCD camera. The gray scales of the images were measured and stored in the computer.



(a)



(b)

Figure 1. Black data insertion. (a) is an ideal case. (b) Actual black data insertion measured.

The DCC block uses a look-up-table (LUT) to generate a boost level by comparing current frame (G_n) data with previous frame (G_{n-1}) data. The boost level is the optimum overshoot needed to cause the liquid crystal to reach target gray level in the shortest possible time. The circuit uses a frame buffer before the LUT to store the previous frame (G_{n-1}). A multiplexer of the circuit will output the boost level from the LUT only if there is a certain difference between G_n and G_{n-1}. Using this method, the inter-gray switching speed can be enhanced 2~3 times.

3. Evaluation of Motion Blur

Figure 3 shows the output image and the gray scale profile. We sent a black-white box with gray scale levels of 0 and 255 respectively, and the background level is 127 in 8-bit system.

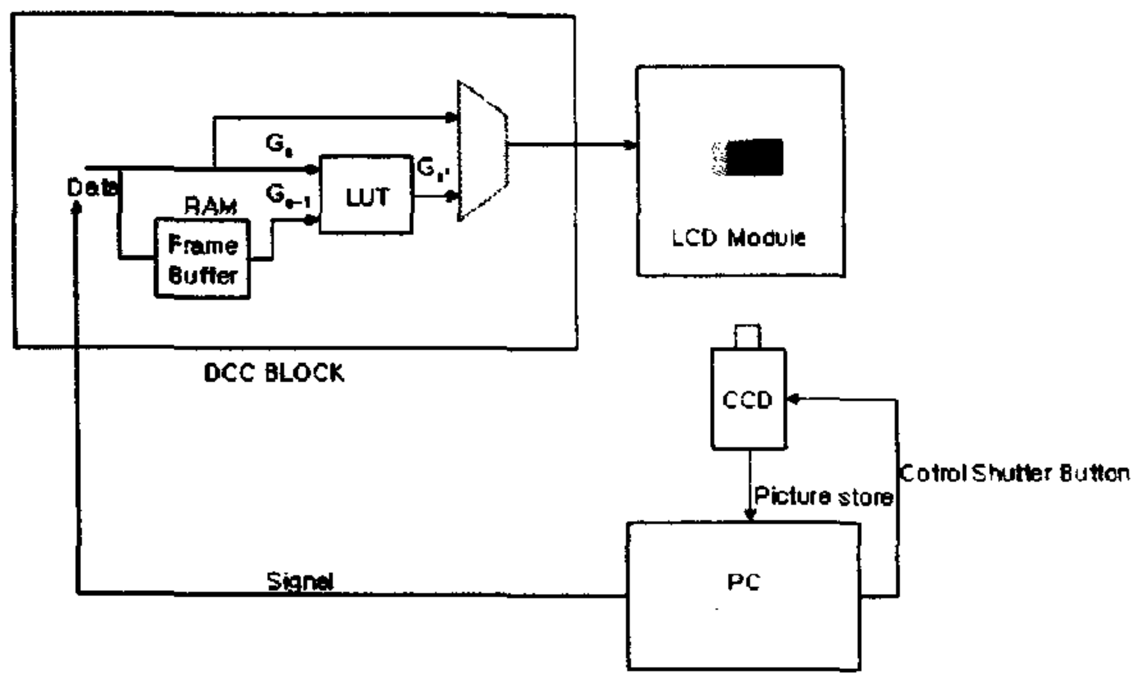
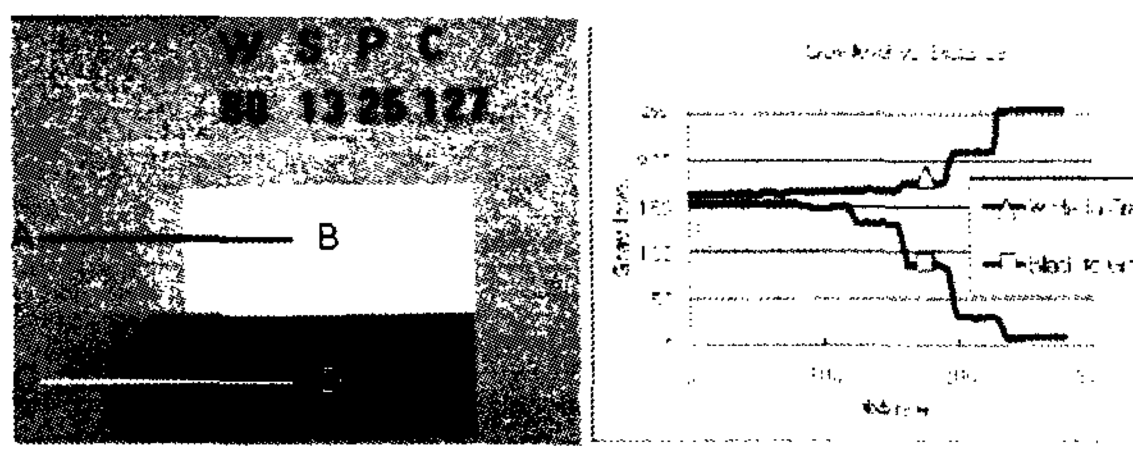


Figure 2. Experimental setup to evaluate motion blur.

The speed of the image in Fig. 3 is 13 pixels/frame with 25% black data insertion ratio and the moving direction is left to right in the figure.

The moving image has extra tail images which cause blurring. The original length of the image is shown as a line above the white box. Also this picture shows that the moving image of the black box has more tails than that for the white box.

This means that response time of black to gray is longer than that for white to gray, and this is true for vertically aligned (VA) liquid crystals. The gray scale was measured between A and B (C and D) in Fig. 3. As shown, the motion blur image has couple of extra tail images on the left side. The gray scale profile was measured from the display. It shows that each tail image has a constant gray scale and the gray scale lines meet near gray level 160 which was originally set to be 127 in data. Also the width of each tail is proportional to the moving image speed. For example, if the speed of a moving image is 13 pixel/frame then each tail has a width of 13 pixels with a constant gray scale.



(a) (b)

Figure 3. (a) The output of blurred image at 13 pixel/frame speed. (b) The gray scale plot of A and B(C and D).

Figure 4 illustrates how this viewing process works. The gray level of the output image is taken at a certain time in the third frame. The moving speed is 2 pixels/frame and LC response time is 3 frame times. The first lowest gray level comes from the first frame's LC level and the second one comes from the second frame's LC level. Therefore the integrated output image has three different gray levels with two pixel widths of the same gray level.

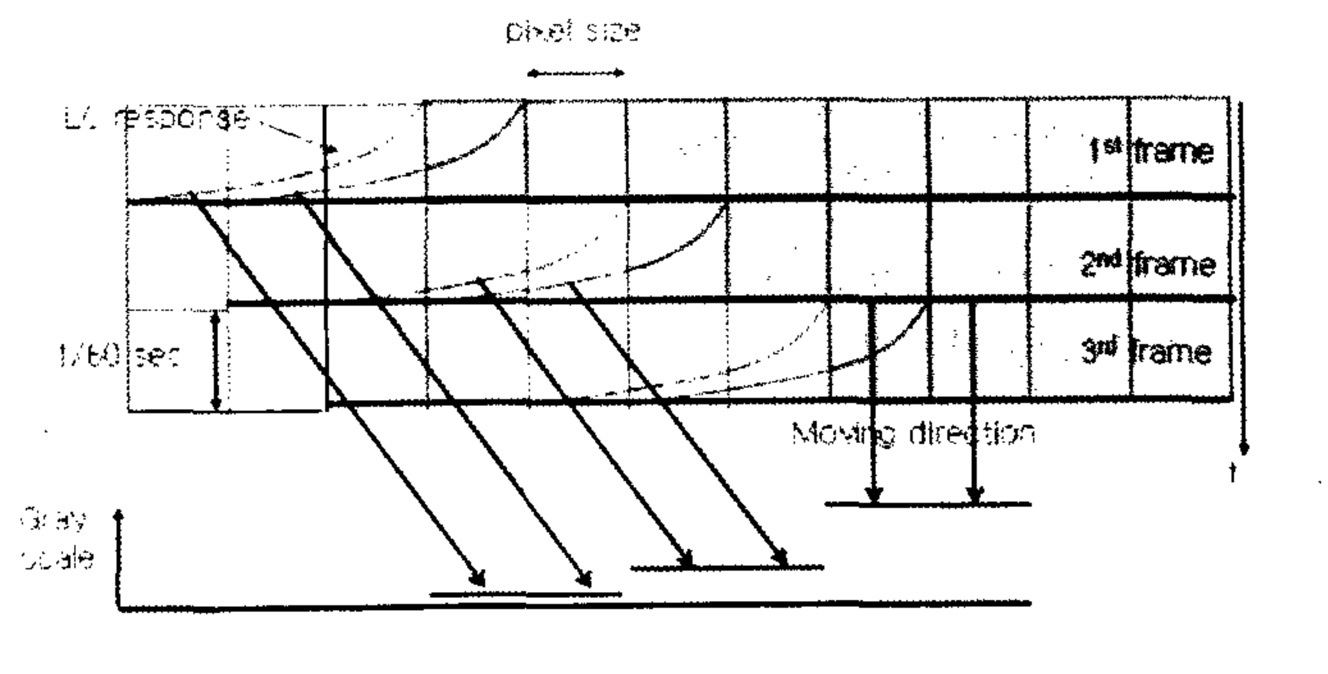


Figure 4. Integrated image for moving image when the moving speed is 2 pixel/frame and LC response time is 3 frame time.

To quantify motion blur we define a motion blur ratio as follows,

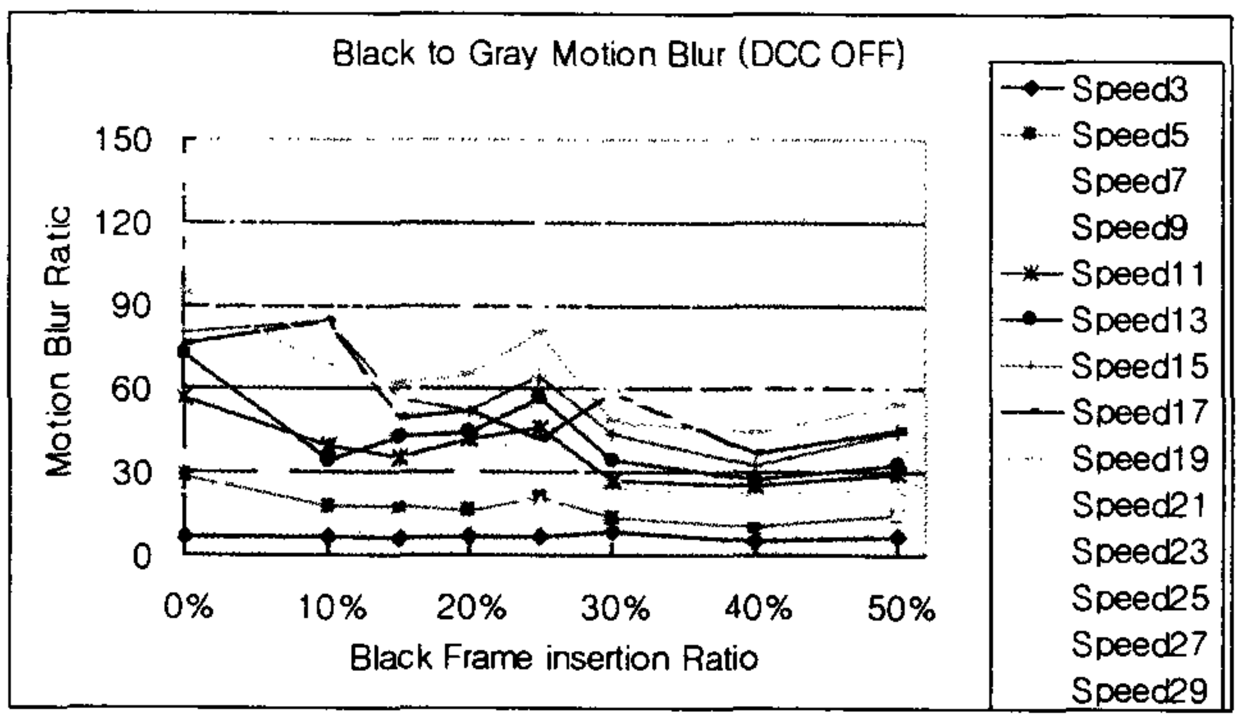
$$MotionBlurRatio = \sum_i \frac{|L_{Ti} - L_B|}{L_B} \times W_i \times \gamma \qquad (1)$$

where L_{Ti} is ith gray level of each tail image, L_B is the background gray level which is originally set to be 127, W_i is the tail width in terms of number of pixels, and γ is a luminance correction which can be caused by different CCD sensitivity. By this formula, a higher motion blur ratio corresponds to more motion blur in the system. We have changed the black frame insertion rate from 0 % to 50 %, and the motion image speed from 3 pixel/frame to 29 pixel/frame. Normally the range of the motion image speed on TV is 10 to 20 pixel/frame.

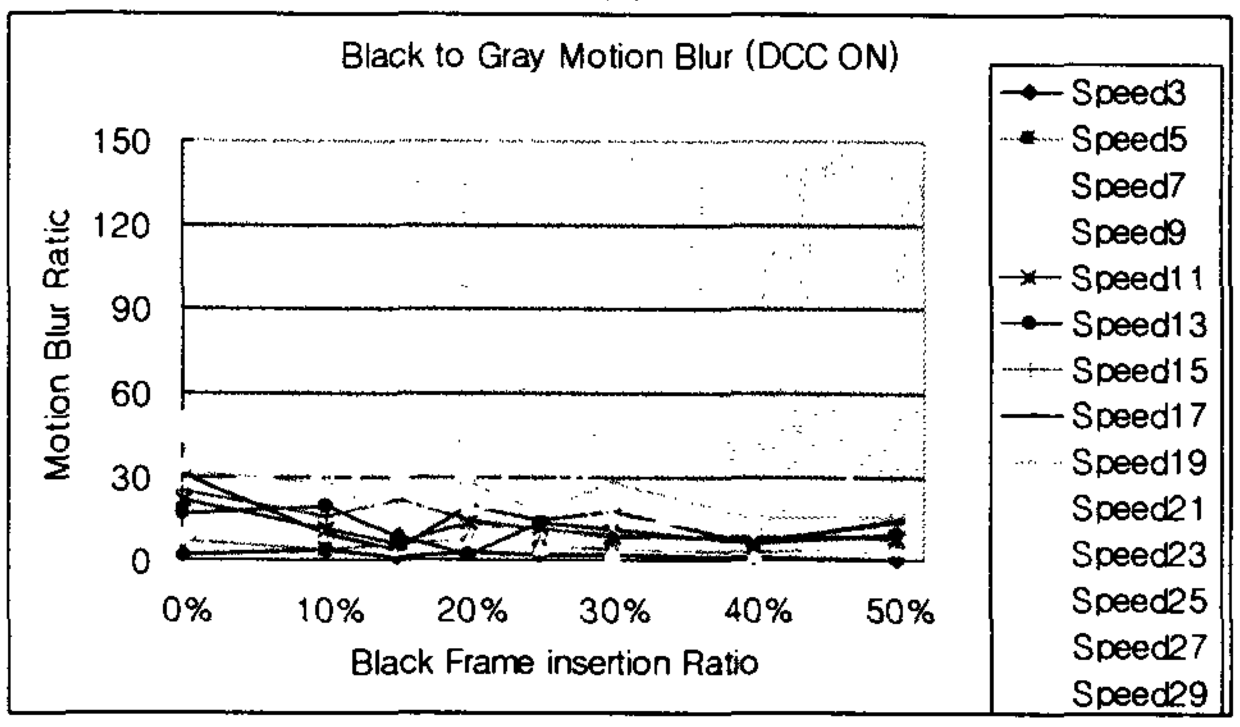
4. Results

Figure 5 shows the measurements. The results show that motion blur starts to be significant when the motion speed is over 7 pixels/frame. The motion blur ratio was observed to be more than 40 for black frame insertion alone in the presence of more than 7 pixels/frame speed. For black frame insertion with DCC, that ratio is less than 40 in most cases as shown in Fig. 5. The figure shows black to gray transition with various motion speeds from 3pixels/frame to 29 pixels/frame. When the insertion ratio was low, high motion blur ratio was observed. Also, when the motion image's speed was increased, more motion blur was observed.

However, for the case of higher black frame insertion over 30 %, motion blur ratio shows less dependence on the image speed. The reason for this is that luminance of full white decreases linearly proportional to the black insertion ratio but the gray level of the tails decreases at a different rate due to different gamma response of each gray level. For this reason, the black frame insertion method should be accompanied with a brighter backlight to compensate for the luminance loss.



(a)



(b)

Figure 5. Motion blur with different black frame insertion ratio and DCC at various image speeds. (a) DCC off, (b) DCC on.

For 50 % black frame ratio with DCC off, the ratio can be reduced up to 44 % of the 0 % ratio and 25 % ratio with DCC off is reduced to up to 69 % of the values. DCC also can reduce these values with additional 20 % for 50 % ratio and 40 % for 25 % ratio in the range of image speed from 3 to 29 pixels/frame.

5. Conclusion

Motion blur in LCDs causes significant motion image quality degradation for LCD TV application. We have shown that DCC and black data insertion are effective tools to reduce motion blur. We have also quantified and measured motion blur with different image speed in LCDs. The motion blur is increased proportional to the image's motion speed and decreased to black data insertion ratio. We found that black frame insertion can reduce motion blur up to 44 % for 50 % black frame insertion and DCC can reduce it with additional 20 % in the range of image speed from 3 to 29 pixels/frame.

6. References

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