Motion Artifact Elimination Technology for LCD Monitors: Advanced DCC

***Seung-Woo Lee**, SuHyun Kwon, Myeongsu Kim, Jun Souk, Sang Soo Kim*
LCD Business SAMSUNG ELECTRONICS Co.,Ltd
#200, Myeongam-Ri, Tangjeong-Myeon, Asan-City, Chungcheongnam-Do, 336-841, Korea (ROK)
+82-41-535-3082, e-mail: swlee00@samsung.com

Abstract

This paper presents a new technology, Advanced Dynamic Capacitance Compensation (A-DCC), for improved dynamic performance of LCD monitors. Conventional LCD monitors suffer from certain specific artifacts, such as wire-frame flicker and line dimming, which are not an issue for the simpler motion images found in television content. A-DCC addresses these more challenging monitor cases through an advanced architecture which analyzes multi-frame data and applies more comprehensive lookup table corrections according to the specific frame sequence.

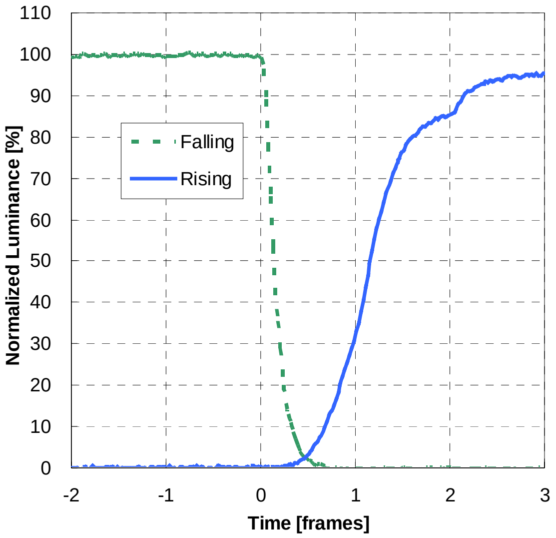
1. Introduction

LCD-TVs require very fast response characteristics to minimize motion blurring in moving images. For many years, motion performance enhancement has been focused (only) on improving transition times for improved motion video. LCD monitors, however, have many more uses than just motion video. LCD monitors are used for rotating rendered or wire-frame 3D graphics. They are used to view rapidly changing high spatial frequency content. They are also used for mapping, games, and driving/flying simulation. As a result, the complicated and dynamic motion contents in LCD monitors can cause additional and severe motion artifacts not conventionally seen in LCD-TVs, including wire-frame flickering, line dimming, discoloration, and others [1].

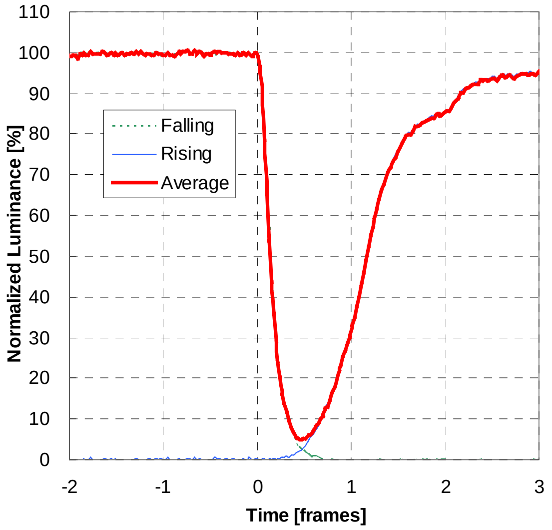
LCD panels for monitor applications have relatively smaller pixel size and run at lower LC temperatures due to BLU differences. Accordingly, LCD monitor panels show intrinsically slower response characteristics compared to their TV counterparts. This paper proposes a new driving technology, Advanced DCC (A-DCC), for minimizing motion artifacts in monitor applications, especially for VA (Vertically-Aligned) liquid crystal mode.

2. Motion Artifacts

Wire-frame flickering: Rotating or moving wire-frame (or mesh) patterns, which are broadly used in 3D CAD, cause flickering on LCD monitors. The cause of this flicker arises from asymmetrical transition times which are commonly seen in VA mode. In a moving wire frame image, brightening and darkening pixels are commingled on the same screen. Because brightening occurs slowly while darkening is very fast, this transition asymmetry causes fluctuation of the average luminance as shown in Figure 1. To minimize wire-frame flickering, it is necessary to speed up the rising time or to slow down the falling time.



(a) Rising & falling response of VA



(b) Averaged (rising+ falling) luminance

Figure 1. Response characteristics of VA when data transition between black and 192-gray level.

Line Dimming: Moving lines on a black background tend to dim according to their speed. The faster the speed, the dimmer the lines become. This phenomenon is also mainly caused by the slow rising response time. Thus, enhanced rising characteristics are needed to solve line dimming.

3. Improvement of Motion Artifacts

3.1 Potential Solutions & Dynamic Transitions

It would seem that improved response time would be an appropriate solution for motion artifacts such as wire-frame flickering and line dimming. However, conventional overdrive cannot improve the black to full white transition, which would suggest that the wire-frame flickering problem cannot be effectively solved by conventional overdrive techniques. Additionally, simple application of overdrive is an imperfect solution in view of dynamic data transitions which arise as a result of applying overdrive. Figure 2 depicts an example of a static transition. In this example, a transition occurs from a stable (long duration) black level to gray level 192. In this case, near-perfect response results from the application of overdrive, in this example 210-gray level.

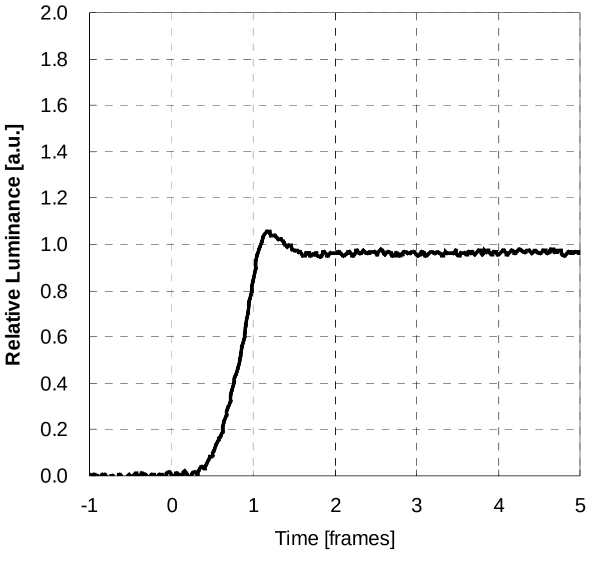


Figure 2. Measured luminance transition (static) of black to 192-gray level when conventional overdrive technology is applied.

Now consider the case where black is present for only one frame, for example the sequence to achieve target luminance levels of 192→black→192→192. In this case, the actual data sequence with overdrive applied would be 192→black→210→192 to compensate for the slow rising (brightening) time. But, the measured luminance transition is very different from that of the static transition as shown in Figure 3.

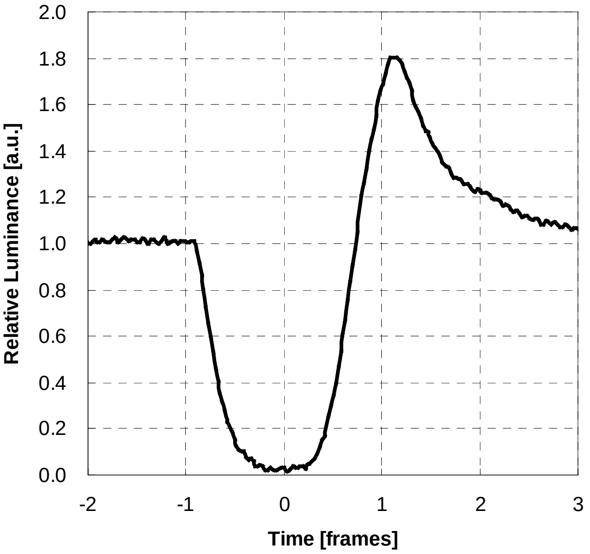
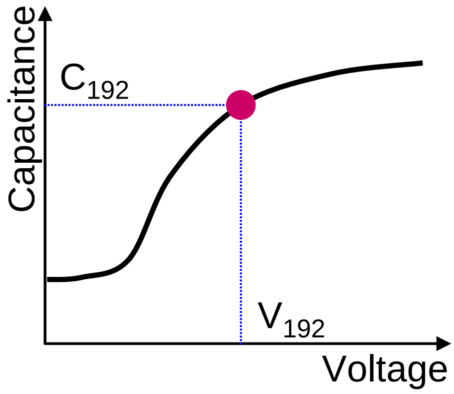
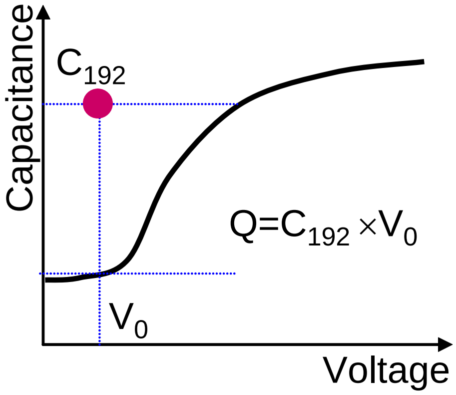


Figure 3. Measured luminance transition (dynamic) of 192→black→192 when conventional overdrive technology is applied.

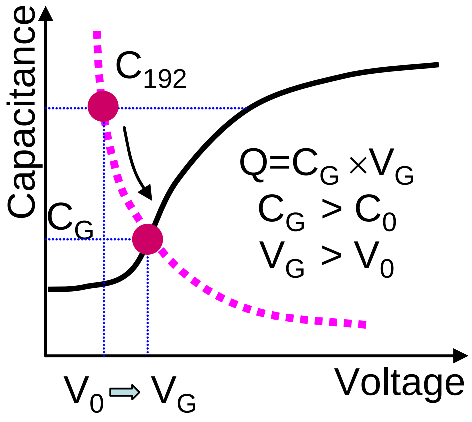
Figures 4b and 4c illustrate the root cause of the difference. Liquid crystal capacitance varies according to the applied voltage. After a static 192-gray level state, black voltage (V_0) is applied to pixel with the LC capacitance of C_{192}. The charge of $Q=C_{192}\times V_0$ is conserved through one frame. But, at the end of the frame, after the LC has changed orientation, the capacitance of LC becomes C_G, which is greater than the capacitance of the black level (C_0). Because of charge conservation, the voltage of the LC becomes V_G, which is higher than V_0. As a result, at the end of the black data time, the LC is not actually at black. Therefore the, overdrive value of 210, intended to optimize the transition from perfect black to 192-gray, causes an over-compensated response for a dynamic transition. This phenomenon is observed only in monitor applications which have smaller pixel sizes and operate at lower LC temperatures. To improve motion artifacts in monitor applications, dynamic transitions should be carefully considered.



(a) Static 192-gray level



(b) Black voltage applied to 192-gray pixel



(c) Dynamic black state

Figure 4. Explanation of dynamic capacitance

3.2 Advanced DCC

For improved monitor performance, this paper has articulated several points thus far: (1) the rising transition needs substantial improvement, (2) falling time could be slower if necessary, (3) black to white transitions are a special case in need of improvement, and (4) dynamic transitions should be carefully considered. To meet all requirements, advanced DCC technology has the following characteristics; (1) pre-tilt [2] and overdrive are applied and extended to all gray rising transitions, (2) data from 3 successive frames are compared and all transition cases are considered. Figure 5 and 6 show the schematic block diagram and the data transitions considered in A-DCC. A-DCC works by selecting the appropriate lookup table (LUT) depending on the transition sequence. Previous concepts have used only a single LUT, which has not been adequate to address monitor-specific issues described above. The selection logic in figure 5 can choose from among either of the two LUTs or from the actual frame values (F_1, F_2, or F_3) for optimum response.

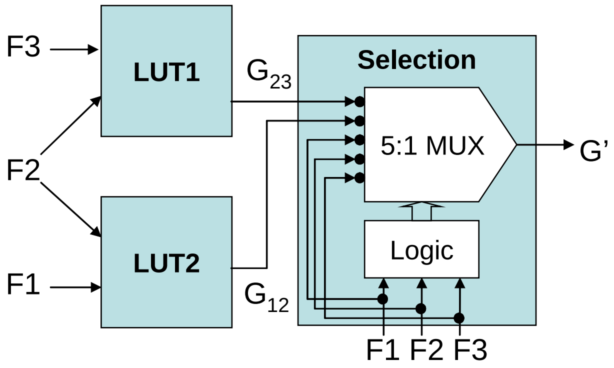


Figure 5. Schematic block diagram of A-DCC; F3 and F1 are the most recent and the earliest data, respectively.

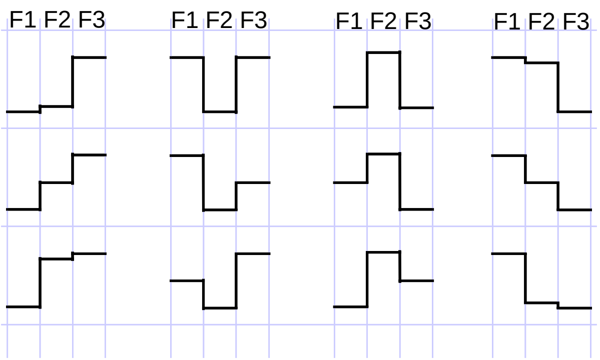


Figure 6. All transition cases are considered in A-DCC

4. Experimental Results

Figure 7 shows a comparison of performance of a rising transition, from black to mid-gray. Even though conventional overdrive shows improvements, A-DCC, which is red line, has faster response than conventional overdrive. Figure 8 shows the application results of A-DCC. Compared with figure 1, the average luminance fluctuation is significantly improved and is limited to one frame time. Dynamic transitions show perfect results as in figure 9. Measured gray-to-gray response time for a 19” A-DCC panel is shown in figure 10. Average G-G response time was 8.1ms and the on-off-on sum time was 13ms. These figures are the top-level performance for LCD monitors with wide viewing angle performance. For wire-frame flickering and line dimming cases, the PVA monitor with A-DCC showed CRT-like performance. The improved rising transition characteristics of A-DCC also substantially improve motion blur performance.

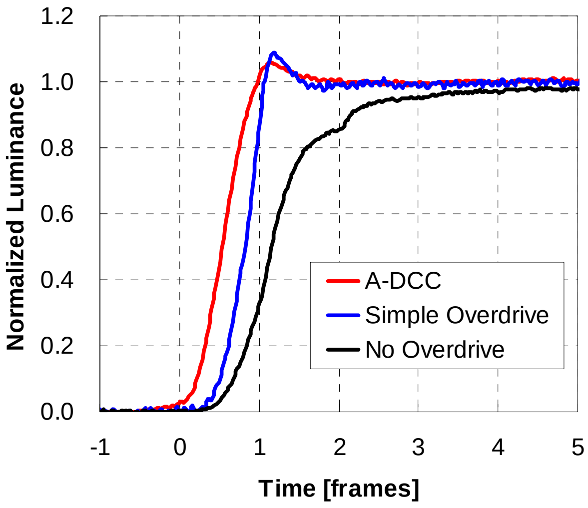


Figure 7. A comparison of performance of rising transition, black to mid-gray.

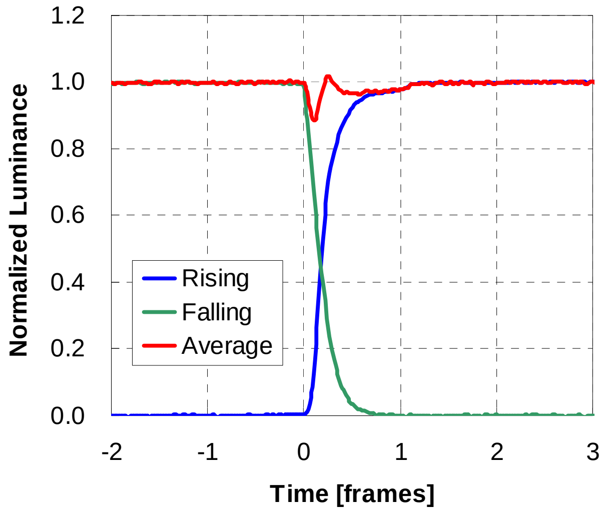


Figure 8. After A-DCC is applied, the average of the luminance shows very improved fluctuation.

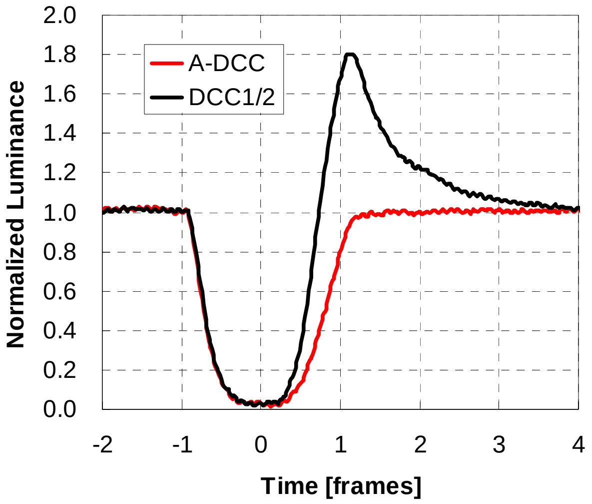


Figure 9. Dynamic transition after A-DCC is applied.

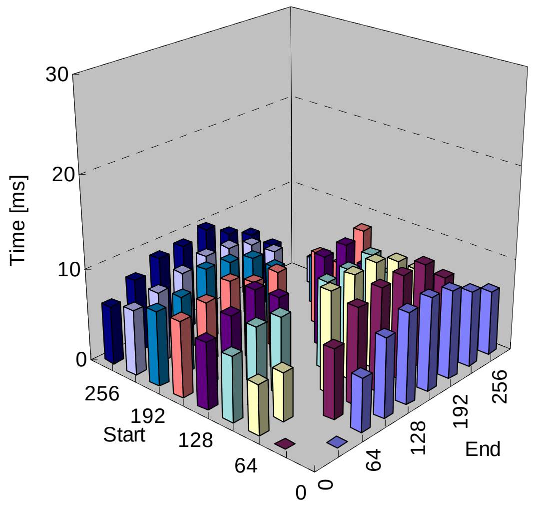


Figure 10. Gray-to-gray transition time after A-DCC. Average of G-G is 8 ms and on+off time is 13ms.

5. Conclusions

A-DCC is the latest overdrive technology. It can effectively eliminate monitor-specific motion artifacts including wire-frame flickering and line dimming, while also substantially improving motion blur performance. We think PVA panel with A-DCC is a very good solution for high-end monitor applications which have complex, high spatial frequency, and dynamic contents.

6. References

[1] Joe Miseli, “Motion Artifacts”, SID 04, Paper 7.3

[2] J.K. Song, et al., “DCCII: Novel method for fast response time in PVA mode”, Paper 48