19.2: Evaluation of Motion Artifacts and Evolving Compensation Techniques for LCD Monitors

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Abstract

Motion artifact concerns for LCDs are driving the display industry in a number of ways, in terms of awareness, understanding, characterization, and ultimately in terms of solutions. Techniques to reduce motion artifacts are quite productive, now reducing artifacts from moving picture content closer to imperceptible levels, and they continue to show improved quality of results. Since 1992, the industry has applied enhanced driving techniques for LCDs to improve motion performance and response times. The LCD-TV market is the primary focus for furthering this development today, and has been for several years.

In 2004, A-DCC, one of the most advanced motion-enhancing technologies, was designed into an LCD monitor. Use of A-DCC dramatically reduced motion artifacts and significantly improved video quality. This paper examines demonstrated results of evaluation and measurements in motion performance of LCD monitors with and without A-DCC. A set of case studies is provided which show a measurable reduction in motion artifacts.

Introduction

The LCD industry regards motion performance for LCDs as a very serious issue to address, and LCD-TVs have become the platform which dominates motion-enhancing technology implementation. Now, the need for motion performance for high end LCD monitors is also considered important, and as of 2004, the first LCD monitors using PVA (Patterned Vertical Alignment) LCD viewing angle technology with A-DCC (Advanced Dynamic Capacitance Compensation) became available. A-DCC is one of the premiere motion-enhancing technologies. It is a variation of DCC-II used for LCD-TVs, except that it is optimized for the more diverse motion artifact applications of monitors.

Note: DCC is termed Dynamic Capacitance by Samsung and applied to PVA technology [3, 4]. It is defined as Dynamic Contrast Compensation by Hitachi and applied to IPS [5]. The techniques are similar, and both are for an overdrive method with frame memory to improve motion performance of LCDs.

This paper shows the effectiveness of motion artifact reduction techniques for LCD monitors. We evaluated motion performance on a number of LCDs, ranging from early-generation 40ms IPS (In-Plane Switching) and the new-generation 16ms IPS (S-IPS), to different generations of PVA, from having no motion performance processing techniques to a modern evolution of A-DCC. For LCDs with A-DCC, we observed and measured dramatic improvements over the version with no A-DCC applied.

The newest generation of A-DCC can be found in high-end LCD monitors, such as the 24-inch 1920×1200 LCD made by Samsung, and implemented in the Sun Microsystems, Inc., 24-in LCD monitor product. Figures 1 and 2 show improvements by use of A-DCC.

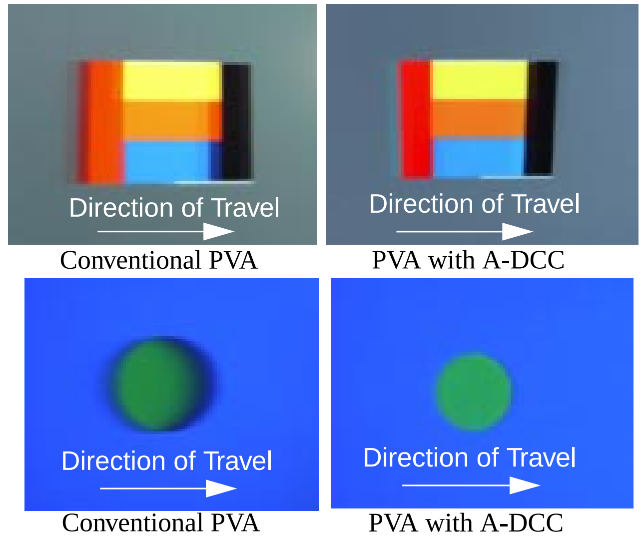


Figure 1: Examples of motion distortion on PVA LCDs without (left side) and with A-DCC applied (right side).

The PVA-LCD with A-DCC greatly reduces the motion blur and color smearing abnormalities, and well as color chromatic aberrations at the leading and trailing edges of the moving objects. Early versions of PVA, like early versions of IPS LCD technology, such as 40ms IPS, showed many cases of motion artifacts about equally as severe.

Other comparisons of PVA with A-DCC show improvements in wireframe flickering and other line motion artifacts. Figure 2 shows moving diagonal lines. Note that the edges of the lines of the moving crosshatch pattern have severe edge distortion for the conventional PVA display, which are corrected by the PVA with A-DCC.

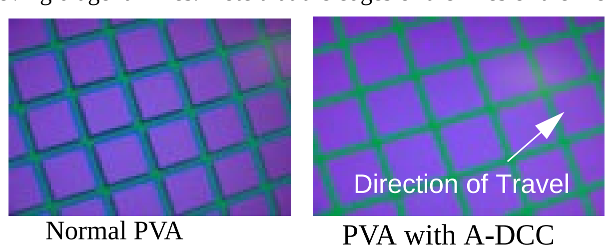


Figure 2: Crosshatch line motion distortion

Technical Summary

There are differences in the motion requirements for LCD-TVs and LCD monitors. LCD-TVs are primarily used only for motion video applications, and require very fast response times to minimize motion blurring. That is the dominant motion issue with LCD-TVs. LCD Monitors have many more uses requiring good motion performance than just video. Here are examples of their applications with regard to motion:

- Controlled graphics motion, such as rotating wireframe 3D graphics
- CAD applications
- Placing fixed display content into motion, such as moving objects, mouse cursors, window repositioning and resizing, scrolling, icon movements, and so forth
- High spatial frequency content movement, and rapid content changing
- Animation
- Motion picture editing
- Also mapping, gaming, modelling, dynamic terrain alteration, driving and flying simulation, etc.

Such items can be especially critical with high performance graphics systems which can continually and smoothly update the complete display array of high resolution monitors at 1/60 second or faster. As a result, many types of motion artifacts can be seen for critical video display content of quality monitors.

A-DCC helps solve motion performance, such as blurred edges, by dynamic compensation. Figure 3 shows how it can be visualized. On the left is a gray moving rectangle with a blurred leading edge

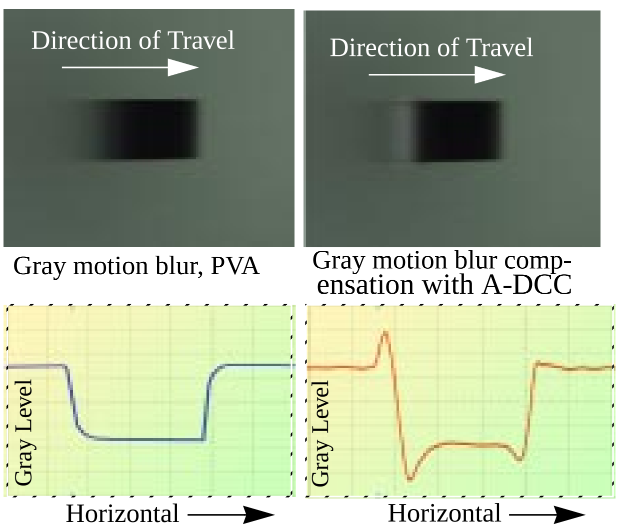


Figure 3: Overdrive to produce edge Enhancement

and smeared tail, as can be found in IPS, TN, or PVA without A-DCC or other types of overdrive and inter-gray level compensation. On the right, the left side shows peaking, driving toward white in place of a dark area after the transition. To the left of the peaking, which goes toward white after the trailing edge of a rectangle in motion (vs. the dark area for the other technology), the smear tail continues. The bright area masks the most noticeable part of the blurred edge, and the last amount of the tail is often very low in contrast with respect to the background and can be unnoticeable, similar to the <10% area of a waveform of a Resistor-Capacitor network fall time response. When this technique is optimal, it makes the motion tail virtually invisible.

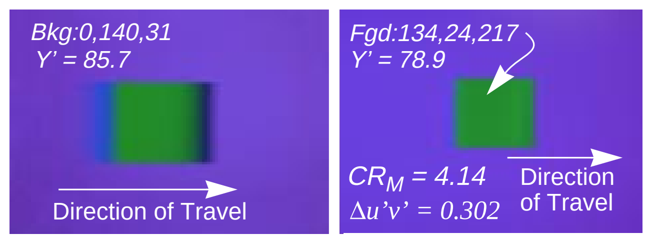
Background

Efforts to enhance the on and off times of LCDs have existed since LCDs were first used for quality displays for computers, when their response times were hundreds of milliseconds.

Conventional methods of improving response times, such as manipulation of the LC (Liquid Crystal) structure and LCD layer refinements have been ongoing. That work got LC response times to be well below 100ms, but more work was needed. As early as 1992 [1], there were publications about overdrive methods to speed the response time of LCDs. This effort has never abated.

Conventional LC technology advancement was not enough. Many other characteristics of motion distortion exist which need greater refinement of LCD response characteristics, such as wireframe flickering, color bleeding, geometric distortions, blurred edge chromatic and inter-blur luminance aberrations, moving line distortions, line-spreading, etc.[2] Some examples of these types of motion artifacts can be seen in the various figures in this paper.

New and more advanced techniques were needed to solve the spectrum of artifacts produced by moving display content. These include increasingly faster response times, balanced rise/fall times, inter-gray level speed increases and matching, and impulsing techniques to help offset the storage time hold-type flicker-free performance that is fundamental to quality LCDs. The goal is to try to make LCDs more CRT-like in their moving picture content characteristics without introducing flicker. The technology and development go on. A-DCC is a promising solution.



Normal PVA (PVA1) PVA with A-DCC (PVA2)

Figure 4: Moving pattern edge blur, with non-symmetrical edges with chromatic/luminance aberrations & color smear, seen for PVA but well-corrected for PVA with A-DCC

Figure 4 shows an example A-DCC improvements motion blur. The green rectangle equivalent luminance level (*Y'*=85.6) is higher

	Response Time (ms)			*MRT* (ms)		
Technology	Rise	Fall	Total	Lead	Tail	MRT
PVA 1	31.25	3.7	34.25	52.6	23.5	76.1
PVA 2	3.27	3.0	6.27	14.5	14.5	23.1
PVA 2*	*(Extreme edge detection)*			24.6	19.0	43.6
**Extra diligence given to perceive the extreme edges of the tails*						

Table 1: Moving pattern edge blur R.T. & MRT

than that of the purple background (*Y'*=78.9). The response time as reported in Table 1 means that rise time is the leading edge, and the fall time is the trailing edge of the rectangle in motion. The table also shows *MRT* (Motion Response Time) measurements using the patented *MAT* (Motion Artifacts detection and analysis Tool) program.[2] That method intrinsically evaluates leading and trailing edges, as well as an geometric or chromatic aberrations. Response time measurements fail to convey the motion-induced distortions.

Equivalent luminance levels are determined by conversion from *RGB* values to Luminance *Y'* as part of the NTSC YIQ transform:

$$Y' = 0.299 \times R + 0.587 \times G + 0.114 \times B$$

Of the various contrast types, Michelson contrast is used, since it is considered to be better for defining luminance levels which are close in value. Michelson contrast constrains an infinite range of contrast to be from 0 to 1, so multiplying it by 100 gives percent of contrast.

$$\%\text{Michelson contrast} = CR_M = 100 \times \left(\frac{Y'_{max} - Y'_{min}}{Y'_{max} + Y'_{min}}\right)$$

MRT (Motion Response Time) is calculated from the *BEW* (Blurred Edge Width) with respect to the speed in Pixels/Frame.

$$MRT = \frac{BEW(lead)}{(Vr \times ppf)} + \frac{BEW(trail)}{(Vr \times ppf)}$$

$\Delta u'v'$ can be used as a metric which defines chrominance variations, and can be calculated either by matrix manipulation of the RGB values or by *xy* CIE chromaticity values measured on the displays used for testing.

$$\Delta u'v' = \sqrt{(u'_1 - u'_2)^2 + (v'_1 - v'_2)^2}$$

A alternate way to evaluate the differences between the color levels is ΔE^*_{ab} CIELUV 1976, which combines both luminance and chromaticity information in a single metric, to help describe how well a change can be seen. It requires characterization of the display used for its luminance and color coordinates as references.

About Measuring Motion Artifacts and Accuracy and Validity of Motion Artifact Methods

In metrology, when we try to determine the quality of a display, we are always plagued by the fundamental problem that it is easy to see anomalies on a display but difficult to quantify them. Such is the case emphatically for motion artifacts.

At the time of this writing, there is no definitive method to accurately, reliably, and unambiguously determine magnitude of motion artifacts, even for the sole case of edge motion blur. It is desirable to evaluate motion artifacts the way the eye sees them, but when one uses instrumentation, it is often not quite clear how the measured results align with respect to the human vision perception or what is real. There are methods proposed, such as smooth pursuit eye-tracking type optical systems, or fast camera sampling, but the method chosen here is an alternate technique, one which closely represents what the eye sees.

The method is *MAT* software system for generating a variety of conditions to produce motion artifacts, with a number of ways to measure them in accordance with human perception. It is a subjective method, perhaps not as accurate as instrumentation, but the results are often more meaningful and useful, since the eye can see much more than any optical system. It is the method which evokes the human visual system to determine the severity of the motion artifacts.

Results

Motion artifact performance has been observed and measured to demonstrate improvements in a number of areas for AM-TFT-LCDs. TN tends to be used for lower end applications, and is intrinsically faster than IPS or VA. Because of its niche and its relatively limited viewing angle range, there is little incentive in the industry to try to improve TN's motion performance. Early generation IPS tends to be somewhat on par or a little better than basic VA type technology, while VA technologies have some intrinsic advantages over IPS. One of the advantages of IPS is somewhat better motion artifact performance then basic VA technology for some cases. VA, especially PVA, has had significant motion enhancement technology developed, now manifesting itself in the newest generation of A-DCC. It is not perfect, and more work needs to be done, but it produces what may be some of best motion performance of any LCD in production today, although the latest generation IPS is generally at the level of motion performance of PVA with A-DCC. Table 4 shows results comparing them.

Following are results for differing technologies on a wide LCD of similar resolution. **Case 1** and **Case 2** use IPS, PVA 1 (no motion enhancements) PVA 2 (A-DCC, first generation), and PVA 3 (A-DCC, current generation. For **Case 3**, two PVA and two IPS LCDs were used, including a current 16ms S-IPS. For that case, PVA 2 is the version with A-DCC.

Case 1: A rectangle of 100×100 pixels of RGB color 21, 241, 224 (like cyan), moves against a background of color 202, 130, 31 (brown-like), at a velocity of -30 ppf (pixels/frame). The pictures were for movement of 225°, or lower right toward upper left.

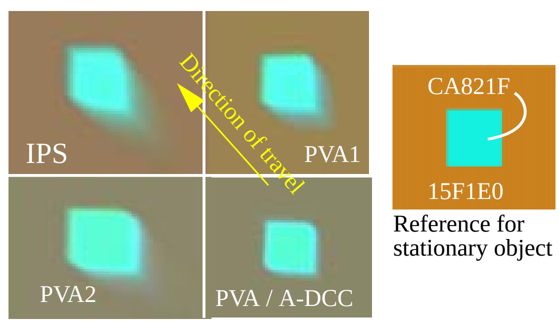


Figure 5: Evaluation of Case 1

The measured results shown in table 2 confirmed what the eye saw, that PVA with A-DCC provided improvement. *BEW* (Blurred Edge Width) is the pixel spread, or the length of visible pixels (motion blur distortion magnitude) at the edge of the object different from than in its stationary condition. *MRT* is Motion Response Time, for the time analogy of the leading and trailing edges of the *BEW* with respect to vertical refresh rate.

	BEW (pixels)			*MRT* (ms)		
Technology	Lead	Trail	Total	Lead	Trail	MRT
IPS1	23	92	125	12.9	51.5	64.3
PVA 1	25	79	104	14.0	44.3	58.4
PVA 2	21	60	80	11.7	33.6	45.3
PVA 3	19	22	41	10.6	12.3	22.9

Table 2: Measured results of Figure 5, Case 1

This case shows a significant improvement in response from PVA with A-DCC implemented.

Case 2: A rectangle of 100×100 white pixels moving against a background of 196 60 174 (RGB 1-256 levels), near magenta, at a velocity of 25 pixels/frame, in a direction of left-to-right.

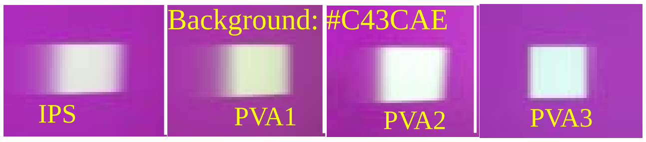


Figure 6: Pictorial Representation of Case 2, a white rectangle moving in a magenta-like background.

The measured results shown in Table 3 again confirmed what the eye saw, that PVA with A-DCC (PVA 3) provided significant improvement.

	BEW (pixels)			*MRT* (ms)		
Technology	Lead	Trail	Total	Lead	Total	MRT
IPS	24	109	133	16.2	73.5	89.7
PVA 1	22	115	137	14.8	77.7	92.4
PVA 2	19	74	93	12.8	49.9	62.7
PVA 3	18	19	37	11.5	12.8	24.3

Table 3: Data for Case 2

Case 3: 40ms IPS, 16ms IPS (S-IPS), conventional PVA, and PVA with A-DCC were compared. The test results are shown graphically in Figure 7. The conditions follow, as well as numerical results in Table 4.

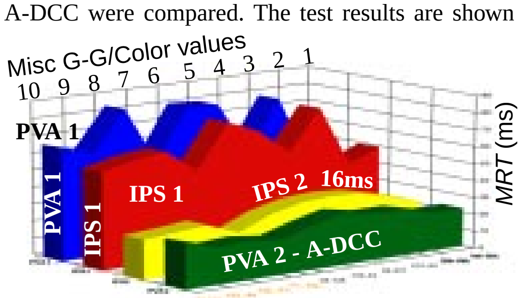


Figure 7: *MRT* graphical results for four technologies, Case 3

- Pattern (foreground): rectangle, 100×100 pixels
- Speed: 15 ppf (pixels per frame)
- Black-White (tests 1-2), Gray Scale (3-6), and Color (7-10)
- 10 arbitrarily chosen foreground/background levels were used.

Conditions of Case 3

Table 4 show the data from Figure 7.

Test	*Background*	*Foreground*	*PVA1*	*IPS1*	*IPS2*	*PVA2*
1	Black	White	49.2	49.2	21.3	22.4
2	White	Black	36.9	41.4	26.8	22.4
3	54	231	78.3	77.2	31.3	26.8
4	231	54	49.2	53.7	32.4	26.8
5	54	126	79.4	68.2	31.2	30.2
6	126	54	80.5	76.1	26.7	25.7
7	122,4,103	71,103,237	50.3	50.3	19.0	20.1
8	71,103,237	122,4,103	83.9	63.8	26.3	22.4
9	53,169,146	122,4,103	60.4	61.5	24.6	21.3
10	122,4,103	53,169,146	66.0	57.0	23.2	26.8

Table 4: *MRT* data results for four technologies, Case 3

Impact and Conclusions

Motion artifact reduction techniques have now been applied to LCDs for monitors. A quality technology, A-DCC, has been observed, evaluated, and measured and shown to provide significant improvement in moving picture distortion. It is a good technology, and shows to be very promising as it evolves even further. It helps set a standard by which future motion quality of LCD monitors will be assessed.

Conclusions

- PVA with A-DCC is significantly improved over conventional PVA, and makes PVA an LCD technology of high quality with regard to types of motion performance.
- Some conventional PVA is similar to some IPS versions for motion blur performance.
- It is difficult to determine a clear winner between current PVA with A-DCC and the latest version 16ms response time S-IPS. They are close in motion performance in many ways, although A-DCC may be a little faster for motion performance, while S-IPS may be a little smoother during the motion blur transitions.
- For any of the comparisons, cases can be found which show better results for one technology or another.
- There are other motion artifact types not reported in this work, which often have markedly different results. Wireframe flickering is an example where displays and technologies vary widely.

This paper demonstrates methods of analysis for motion artifacts using *MAT* (Motion Artifacts detection and analysis Tool), which can test motion performance on different types of displays in ways which measure many types of motion parameters. Since it uses the eye as the measurement instrument, it has a great deal of versatility for motion performance investigation. Some findings from its use will help define the Motion Artifacts section of FPDM3. [6].

References

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