

## 69.3: Invited Paper: Advanced MVA for High Quality LCD-TVs

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### Abstract

We proposed an advanced MVA, AMVA (Advanced MVA or AUO MVA), which has the features required by an advanced LCD-TV. AMVA has the true wide viewing angle, high color saturation and fast response speed for motion picture displaying. Besides, the image processing techniques to enhance the image performance with vivid color and sharpness are also obtained. AMVA has become the promising solution of advanced LCD-TV panels for mass-production.

### 1. Introduction

MVA has been the most applicable mode applying to LCD-TVs because of its high contrast, wide viewing angle and large size compatible in comparison to IPS. However, color-washout issue [1, 2] remains as the urgent case that needs to be solved.

We developed AUO's AMVA that can meet the features an advanced LCD-TV requires. It has the true wide viewing angle ( $> 88^\circ/88^\circ/88^\circ/88^\circ$ ) in terms of contrast ratio ( $>1200:1$ ), color shift ( $\Delta u^*v^* = 0.01$ ) and color washout; the high color saturation in terms of both saturated colors (R, G and B) and non-saturated colors (Skin tone, grass-green, and sky-blue); the fast response speed in terms of rising and falling (on and off) response time ( $T_{on} + T_{off} < 16ms$ ), gray-to-gray (GTG = 6ms) switching time, and Motion Picture Response Time (MPRT = 15ms [holding type] /  $< 8ms$  [pulsed type]). Besides, we can also implement image-processing techniques to enhance image quality with vivid color and sharpness within gray levels [3]. Our AMVA has double domains (8 domains) that are automatically generated without doubling the source lines/ICs nor the gate lines/ICs. Our 8-domain AMVA enables the capabilities of not only the color washout improvement but also the automatic over-driving compensation to result in better response time.

### 2. Eight-domain (8-domain) AMVA

#### 2.1 Basic scheme of AMVA

Our AMVA applies a novel pixel structure to provide the improvement on the color washout issue without changing any driving scheme. AMVA keeps the conventional TFT-LCD driving scheme -- an uni-pixel subjected to one gate-line, one source-line, and one com-line as well a normal timing controller (Tcon) used to current MVAs. Even thus, the 8-domain configuration can be automatically generated without doubling the source lines/ICs nor the gate lines/ICs. The pixel-rendering method to simulate 8-domain is not also considered because of the serious artifacts generated.

#### 2.2 High CR improvement

For better CR in AMVA, we have developed the implementation of good color-resist to reduce the depolarization effect occurring as light passing through it. Besides, we also modify the pixel structure to lessen the light leakage of a pixel at the dark state to

conduct the presence of a true black. With optimizing the compensation of polarizer, wide viewing angle in terms of CR and saturated color shift (say, R, B, and B color shift) can be achieved.

For those color shifts occurred during the displaying of composite colors (i.e., non-saturated color shift), for instance, skin color, grass green color, and sky blue color are shown, we can see the colors faded as we increase the viewing angle. The reason has been clarified to due to the dispersion of gamma curve as the function of viewing angle. The dispersion for R, G and B colors are not identical to each other so that a composite color can't keep the same ratio as viewing angle increases.

Our AMVA shows very good performance for advanced LCD-TV panels. The performance of conventional MVA and AMVA can be observed in Figure 1.



**Figure 1. The photograph of (a) conventional MVA and (b) AMVA viewed from normal, right, and left sides.**

#### 2.3 Generation of 8 domains

AUO has already tried some approaches to resolve the problem of color washout and finally we successfully developed the ART (Additional Refresh Technology / Advanced Response Time) technology to generate 8 domains in our AMVA pixels. The 8-domain AMVA applies two sets of conventional 4 domains (each domain indicates one aligning direction along azimuth,  $\phi$ ). The two sets having different LC molecular tilting angles ( $\theta$ ) are

automatically generated under the identical data voltage string used in conventional MVA. Accordingly, we don't need to make the frame rate double by data string re-synthesis, which may consumes double data bandwidth. We don't need to use the costly way of two times of data lines/ICs for getting the double domains, neither. Of course, the pixel rendering method by using two uni-pixels for representing one double-domain uni-pixel is not preferable due to its unacceptable artifact and resolution reduction. It is very easy to find the artifacts of slant lattice spots in the displaying image so that the spatial frequency of image is very low for acceptance. Other than above mentioned, there still exists a method by using more electrodes subjected to specifically created signals to generate two sets of tilting  $\theta$ . This scheme is complicated from driving and process point of views and the domain configuration within an uni-pixel has less flexibility for spatial frequency improvement. Thus, it also exists some artifacts according to the image quality. Figure 1 shows the microscopic photograph of our 8-domain AMVA pixels at different gray levels.

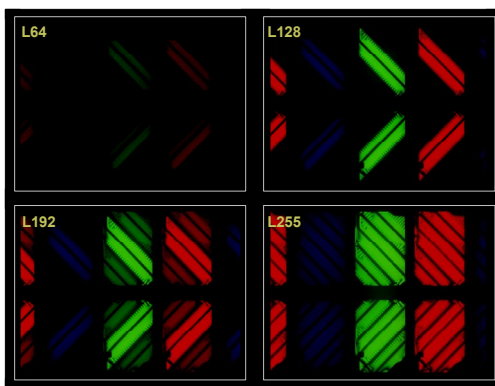
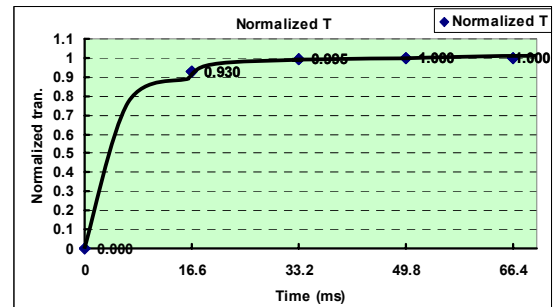


Figure 2. The microscopic photograph of 8-domain AMVA pixels at different gray levels.

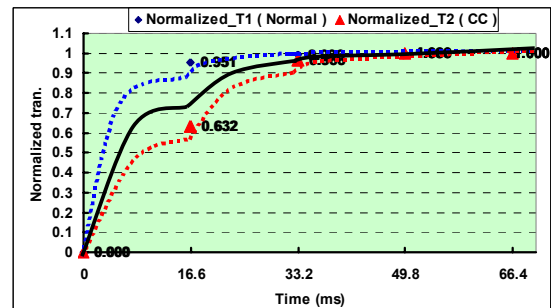
## 2.5 ART for over-driving compensation

With ART technology, AMVA also provide a premium on the gray-to-gray response time. We can regard the total optical characteristics as the sum of two respective sets. If we define T1, T2 and T as the transmittances of 1<sup>st</sup> set of 4-domain, 2<sup>nd</sup> set of 4-domain, and total 8 domains, respectively; (while A1, and A2 as the areas of 1<sup>st</sup> set of 4-domain, and 2<sup>nd</sup> set of 4-domain, respectively), the total transmittance  $T = T1 \cdot A1 / (A1 + A2) + T2 \cdot A2 / (A1 + A2)$ .

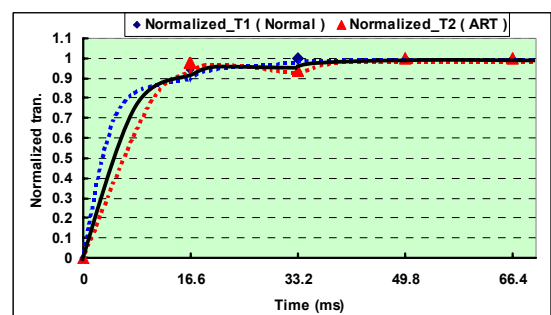
From Fig. 3(c), it can be easily found that ART provides a very good combination of T1 and T2 to have the better fast response curve. The curve T1 from normal area (1<sup>st</sup> set of 4-domain) seems to be accelerated by over-driving in comparison to curve T2 from ART area (2<sup>nd</sup> set of 4-domain). If we consider one another possible automatically 8-domain generated method, CC (Capacitive Coupling), it can be found that CC shown in Fig. 3(b) has even worse response time as compared to normal MVA shown in Fig. 3(a). In this case, the response times of normal MVA, CC, and ART (AMVA) are 17ms, 24ms and 14ms, respectively. Accordingly, the gray-to-gray response of ART also performs well because the automatic over-driving compensation is carried out.



(a)



(b)



(c)

Figure 3. The response curve of (a) conventional MVA, (b) capacitive coupling and (c) ART (AMVA).

## 2.6 Domain Configuration for human perception

With both the advantages of automatic 8-domain generation and over-driving compensation, AMVA also has another wonderful performance for its good perceived resolution.

If we compare AUO's AMVA with the doubling source lines/ICs (DS), the doubling gate lines/ICs (DG), the two pixel-rendering method (TPR) and Multi-com electrodes (MCE) subjected to specifically created signals. AMVA has better flexibility in domain configuration so that its spatial frequency is the best for human perception. Figure 4 shows the domain configuration of the sub-pixel for different type of color-washout solutions. We can easily found that AMVA in Figure 4 (c) belonging to zigzag interlace type has the best perceived-resolution; while DS, DG and MCE belonging to 1/2 sub-pixel rendering have worse perception with the domain configuration as shown in Figure 4 (a). TPR has the worst resolution because it is not true 8-domain but use 2 sub-pixels to simulate as shown in Figure 4 (b). The TPR almost can

not be acceptable because it sacrifices one half of the resolution. For practical image observed from these different technologies, we can found that AMVA has a very smooth and good image quality due to its specific arrangement of 8 domains from Figure 5 (a). The remained technologies including DS, DG, TPR and MCE all have very serious artifacts due to the improper domain configuration. The artifacts brought from DS, DG, MCE and especially from TPR can be categorized into lattice defect (all area of the image) and unsmooth curvature (cheek boundary of the face) as seen from Figure 5 (b).

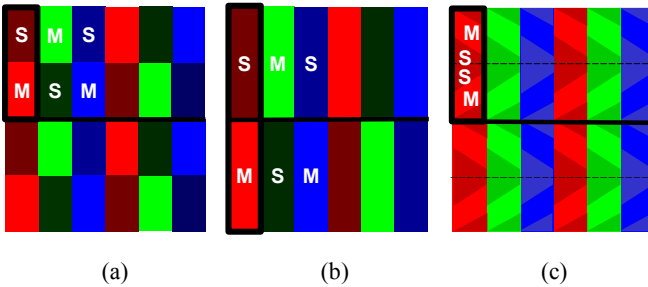
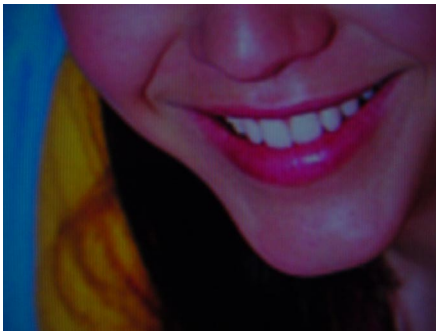
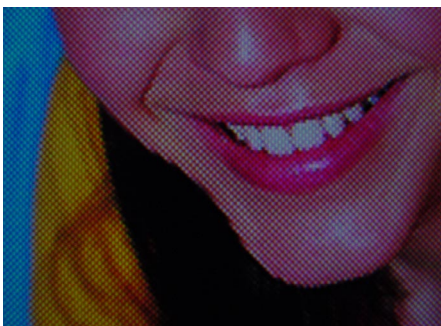


Figure 4. The domain configuration types of sub-pixel for different type of color-washout solutions: (a) 1/2 sub-pixel rendering, (b) sub-pixel rendering and (c) zigzag interlace. (M:main domains; S: sub-domain)



(a)



(b)

Figure 5. The picture quality observed from (a) AMVA and (b) other methods including DS, DG, MCE and especially from TPR that has artifacts of lattice defect and unsmooth curvature.

### 3. High color saturation by HiColor

AMVA with ART technology has been the standard feature in AUO's TV panels from now on. It brings us the un-faded non-

saturated colors (Skin tone, grass-green, and sky-blue) to keep the good color saturation for oblique viewing. We also develop the further improvement of saturated colors (R, G and B) by optimizing the color spectrums of both color filter and CCFL lamps. Before LED overcoming its bottleneck of high cost and power consumption, CCFL backlit is a good choice for high color saturation panels. The technology HiColor developed by AUO can give 92% of NTSC. We can see the improved color saturation especially in green color and red color. While blue color is not sensitive to human eyes so that it can be remained for the next step of improvement. Figure 4 shows us the CIE diagram of the R, G and B color coordinates of the conventional 72% NTSC and the HiColor 92% NTSC. We can found that the green has been dramatically improved more and red is also improved. For blue color, we can still improve more but it is relatively insensible to human eyes. With using CCFL lamps, we can also achieve a very good color saturation performance.

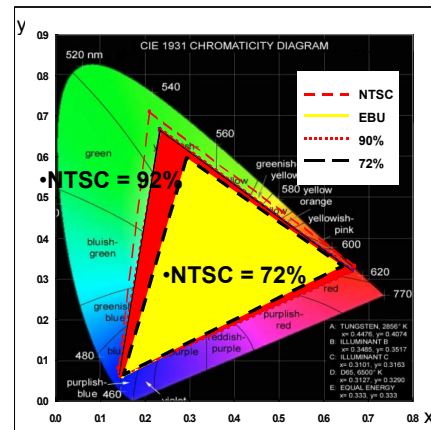


Figure 4. HiColor provides 92% of NTSC coverage on the CIE color chromaticity.

## 4 Improvement of motion picture quality by SPD

Another important factor considered in an advanced LCD-TV is the motion picture quality.

### 4.1 On-off response time (Ton + Toff)

The index of Ton + Toff is more suitable for text displaying such as in laptop and desktop displays because the black (L255) and white (L0) levels are the major levels among a text image. Generally speaking, the typical value of the on-off response speed (Ton+Toff) for MVA is bigger than 20ms. The conventional way to decrease the (Ton+toff) value is to optimize the LC parameters, reduce the cell gap and increase the driving voltage. While the configuration of a MVA pixel imposes a limitation for further response time improvement because of its inhomogeneous distribution of both electrical field and LC orientation. AUO developed the suitable pixels together with the conventional optimization ways to obtain the (Ton+Toff) < 16ms.

### 4.2 Gray-to-gray response time (GTG)

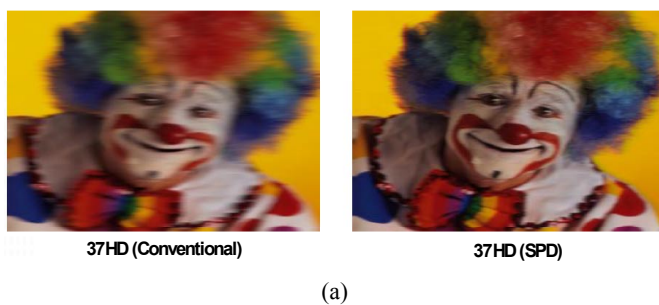
Other than (Tn+toff), in fact, we would rather consider the gray-to-gray (GTG) response time because it is more meaningful for LCD TVs. Because video image including a lot of switching



among gray-levels ( $L_x$  to  $L_y$ , where  $x, y = 0 \sim 255$ ); not between only black ( $L_{255}$ ) and white ( $L_0$ ) levels. Due to the automatic over-driving compensation carried out from ART, the practical over-driving imposed, and the improvement of basic response level of (Ton+Toff) from optimizations, the GTG of AMVA can be effectively improved to 6ms.

### 4.3 Motion picture response time (MPRT)

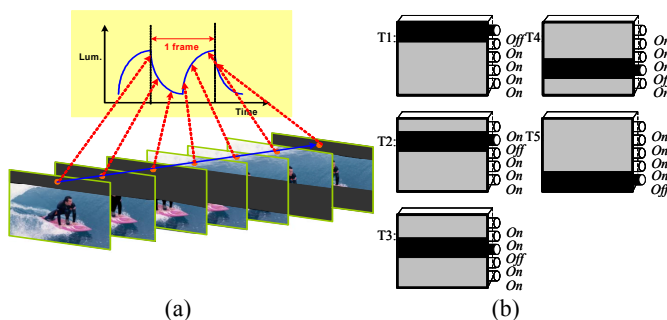
For motion picture quality, a more promising index to represent the response speed is MPRT. The limitation of MPRT value for conventional holding type displays can only reduced to the value around 14~16ms. We developed the Simulated Pulsed Driving (SPD) do make MPRT further improved. Because our SPD applied the simulated pulsed type driving from panel and/or backlit, the MPRT can be <8ms..Especially for the pulsed driving on a panel, we don't need to make double frame rate operation so that it is very promising for full HD resolution.



(a)

(b)

Figure 5. SPD technology shows (a) a very good motion blur reduction and (b) a very good MPRT.



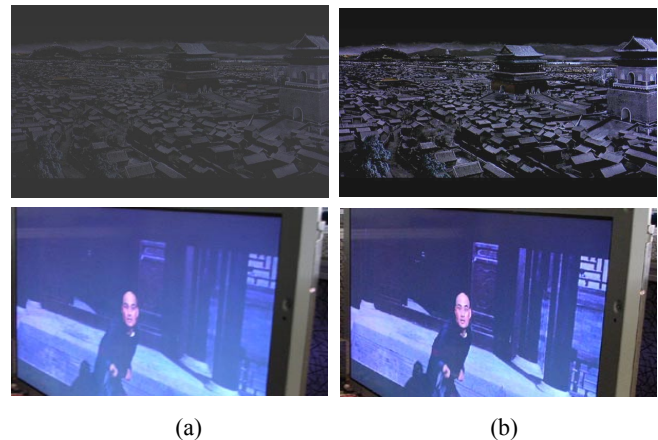
(a)

(b)

Figure 6. SPD applied the simulated pulsed type driving from (a) panel and/or (b) backlit. The MPRT can be reach <8ms.

## 5. Image processing techniques

We also developed the image processing technology to improve the image quality [3, 4]. Color temperature calibration, contrast enhancement, saturation enhancement, sharpness enhancement, and dithering Function are carried out. Dynamic CR extension to reach CR > 2500:1 or more as shown in Figure 7 is also developed for the advanced LCD TV. This DCR technology can have a very good CR improvement according to the displaying image and can save the powering consumption by 30%.



(a)

(b)

Figure 7. Dynamic CR to improve contrast ratio and image detail with low power consumption: (a)normal and (b) DCR.

## 6. Conclusion

Our AMVA has double domains that are truly automatically generated with neither doubling the source lines/ICs nor the gate lines/ICs. The 8-domain AMVA enables the capabilities of not only color washout improvement but also the automatic over-driving compensation for better response time. AMVA is one of the most applicable ways to be used in all sizes of LCDs. HiColor and SPD technologies are also carried out to have good color saturation and motion picture quality, respectively. Besides, the image processing techniques to enhance the image performance with vivid color and sharpness are also obtained in our LCD TV panels. AMVA, HiColor and SPD have been applied to AUO's products.

## 7. References

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