Advanced-MVA(A-MVA) Mode for High Quality LC Displays

Yi-Pai Huang[1], Wei-Kai Huang[2], Cheng-Han Tsao[2], Jeng-Jia Su[2], Hong-Lung Hou[2], Pei-Chun Liao [2], Chung-Yi Chiu[2], Chia-Yu Lee[2]

[1] **Display Institute, National Chiao Tung University, Hsinchu, Taiwan, R.O.C.**
TEL:886-3-5712121 ext 52924, e-mail:boundshuang@nctu.edu.tw
[2] **AU Optronics Technology Center, Science Park, Hsin-Chu, Taiwan, R.O.C.**

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Abstract

Advanced-MVA(A-MVA) for LCD-TV application was proposed to yield high performance LCD-TV. By utilizing Additional Refresh Technology(ART), which has 2-TFTs but with single source and gate line only. The A-MVA can yield low color washout, fast response, and optimized brightness. AMVA has become the promising solution of advanced LCD-TV panels for mass-production.

1. Introduction

The digital TV market of liquid crystal display television (LCD-TV) has dramatically increased in recently. Multi-domain vertical alignment(MVA) technology[1], which separates a sub-pixel into 4-domains, has been the most applicable mode applying to LCD-TVs because of its high contrast, wide viewing angle and large size compatible. However, color washout at large viewing angle[1],[2,[3] and slow response time are the remained two issues that will degrade the image quality of MVA mode.

For reducing color washout, the most efficient way is to increase the domains in a sub-pixel from 4 to 8 or more. 2-TFT pixel such as dual data or dual gate(T-T type)[2],[3], and common voltage swinging(Com-swing)[4] technologies were proposed to generate the 8-domains. However, both T-T type and Com-swing technology required extra ICs and electronic components that may increase the cost. Beside, they required 2-TFTs that may results in different optimized common voltage(Vcom), and induces serious flicker.

In order to shortening the response time, overdriving(OD)[2],[3] were proposed. Nevertheless, OD technology only can improve the gray to gray(GTG) response time, but has no function for the rising(Tr) and falling(Tf), and it requires an extra look up table to store the overdriving level.

Advanced-MVA(A-MVA) [5],[6],[7] mode with Additional Refresh Technology(ART) was proposed for to achieve low color washout and fast response time without any additional cost. Moreover, ART can adjust the brightness and the grade of color washout by controlling the gate signal, thus increases the flexibility for design and fabrication.

In this paper, we will present a novel A-MVA mode, which was optimized by utilizing additional refresh technology(ART), gray-level ratio distortion (GRD) and inside sub-pixel dynamic observation (ISDO) methods.

2. Advanced-MVA(AMVA) Mode

2.1 Additional Refresh Technology (ART)

The Additional Refresh Technology(ART) generates an 8-domains sub-pixel with self-overdriving function thus can not only reduce the color washout but also shorten the response time. ART is a novel pixel design technology which divided a sub-pixel into main- and sub-regions to yield 8-domains (4 azimuthal x 2 polar), as the pixel circuit shown in Fig. 1.

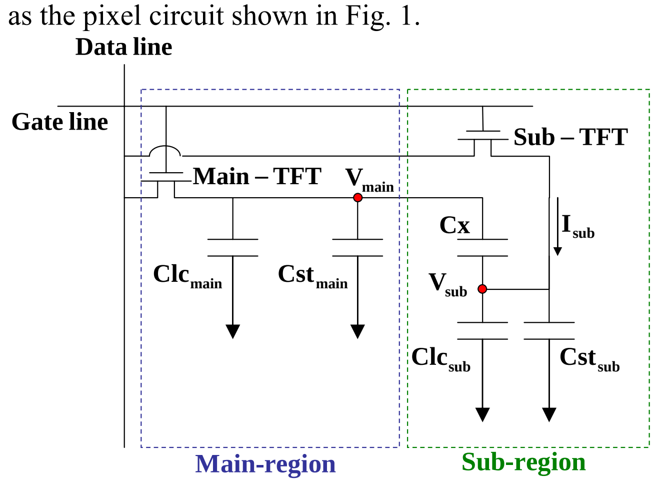


Fig. 1. The pixel circuit of additional refresh technology (ART) in AMVA mode.

ART utilized an additional TFT(Sub-TFT), which has different W/L and charging ratio to the main-TFT, to refresh(recharge) the voltage of sub-region(Vsub) in each frame. The Vsub voltage can be written as following equation:

$$V_{sub} = V_{Coupled} + V_{Charging}$$
$$= \left(\frac{C_x}{Cst_{sub} + Clc_{sub} + C_x}\right) \cdot V_{main} + \int_0^{T_{gate}} \frac{I_{sub}(t)}{C_{total}} dt$$

where Cst_{sub} and Clc_{sub} is the storage and LC capacitance of sub-region. C_x is the coupling capacitance. V_{main} is the voltage of main-region. T_{gate} is the time that sub-TFT was turned on in a frame. Isub is the charging current of sub-TFT. Therefore, by simply modifying C_x and I_{sub} from pixel layout, the V_{sub} can be optimized for reducing the color washout without any extra high cost components. Additionally, due to the recharge(refresh) of sub-TFT in each frame, the ion will not accumulate on the electrode thus can suppress the image-sticking issue.

Except the improvement of color washout, ART also has self-overdriving function, Due to the initial voltage affects the charging ability of sub-TFT, the 1st frame of low gray level to high gray level always has higher V_{sub} voltage than the rest frames, thus can speed up the LC rising response automatically.

2.2 Gray-Level Ratio Distortion (GRD) for Off-axis Image Optimization

Special single color was used to roughly evaluate the color difference(Δu'v') between on and off-axis viewing. However, the off-axis image quality of a display cannot be fully evaluated by using a single color image. Therefore, we proposed the "Gray-level Ratio Distortion" index (GRD(θ, φ)) [6] to provide a more precise evaluation index. The color of an image was mixed by the R, G, and, B with various gray levels. The gray level means the normalized brightness ratio. Therefore, by keeping the same R, G, and B brightness ratio of on- and off-axis, the image color could be almost the same. Gray-level Ratio Distortion (DRG(θ, φ)) value, as show in following equation, calculated the ratio difference of different gray levels between on- and off-axis to evaluate the color distortion at large viewing angle.

$$GRD(\theta,\varphi) = \left\langle \left| \frac{\left(\frac{T_{m(\theta,\varphi)}}{T_{n(\theta,\varphi)}}\right)_{Off-axis}}{\left(\frac{T_{m(\theta,\varphi)}}{T_{n(\theta,\varphi)}}\right)_{On-axis}} - 1 \right| \right\rangle_{m,n=gray-level}$$

where, T_m = Normalized brightness of level m.
θ = Polar viewing angle.
ϕ = Azimuthal viewing angle.

According to the human factor experiment, GRD from L64 to L216 can almost match the value of human factor experiment. The results indicated that GRD(L64~L216) can truly represent the color washout grade of a full color display device. Consequently, the GRD value was utilized as the optimized parameter when designing the A-MVA.

2.3 Inside Sub-pixel Dynamic Observation (ISDO) for Flicker Optimization

Inside Sub-pixel Dynamic Observation(ISDO) method was proposed to measure the optimized Vcom for 2-TFTs pixel. The setup and the block diagram of the quantification scheme are shown in Fig. 2. In ISDO part, the microscope is connected to the FastCCD system (FASTCAM-ultima 512, PHOTRON corp.) which has high recording rate up to one image per mini-second.

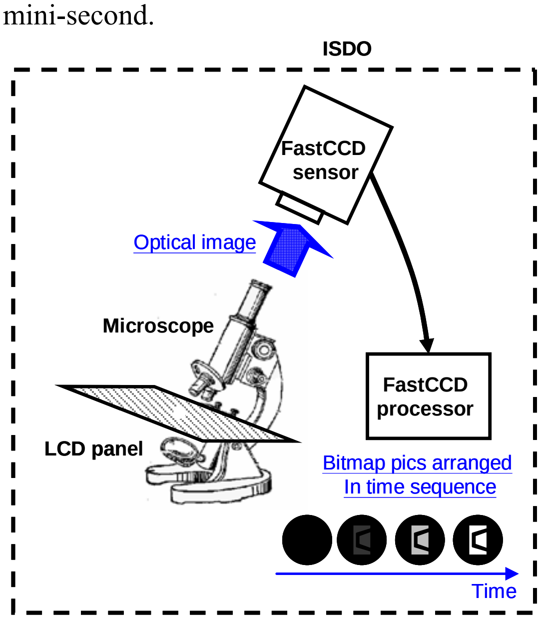


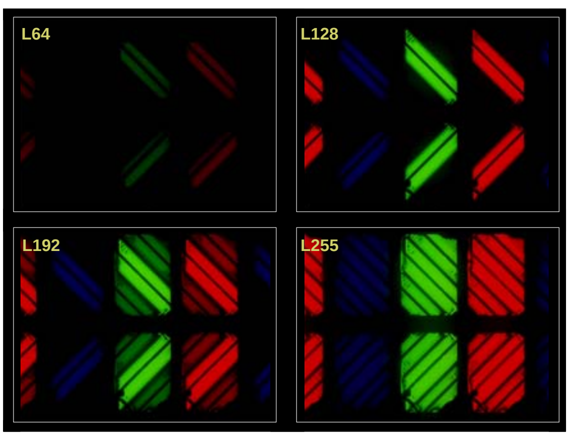
Fig. 2. ISDO setup and quantification scheme

The FastCCD system records images in time sequence and extracts them into the bitmap format. The mutual relation between the bitmap gray level and the panel brightness is tested to be linear. After ISDO, we propose a scheme to quantify the data. First is to design the mask, which is actually an ISDO image with area-specified patterns. With proper mask settings, we can extract the gray level of the specified area in all ISDO images. The data arranged in time sequence represents the local dynamic response. It can be utilized for following analyses, such as local flicker measurement and the micro-structure LC response.

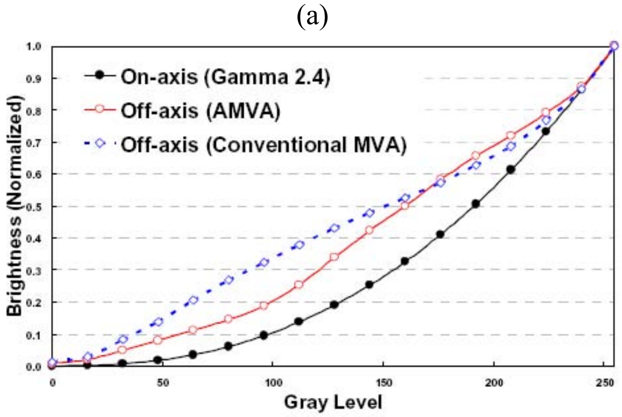
3. Experiment Results and Discussion

3.1 Low Color washout

From the GRD evaluation method, the pixel which can yield lower GRD(L64~L216) was designed. The Fig. 3(a) shows the optimized 8-domain pixel image by applying ART on A-MVA mode. The gamma of the A-MVA panel at on- and off-axis were measured and shown in Fig. 3(b). The GRD value of the panel at θ=60°, φ=0° is 0.22 which demonstrates a much improve than that of conventional MVA mode(0.40).



(a)



(b)

Fig. 3. (a) The A-MVA pixel image, and (b) the optimized gamma (GRD(60°,0°) = 0.22) of a 32" WXGA LCD-TV.

3.2 Fast Response Time

ART technology also provides a premium on the LC rising response time. Because of the mentioned self-overdriving property, the rising time(Tr) of ART(AMVA) and conventional MVA are 10ms and 15ms respectively (Fig. 4.). ART has much automatically improvement (~30%) of LC response without using any electronic overdriving technique.

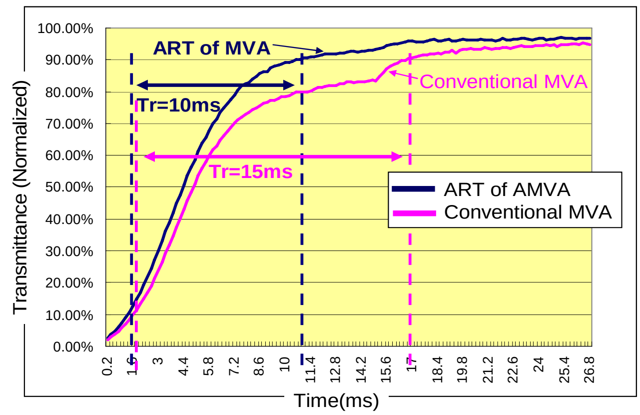
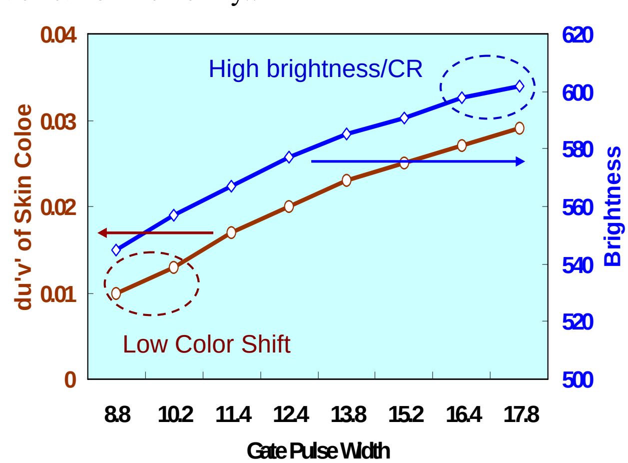


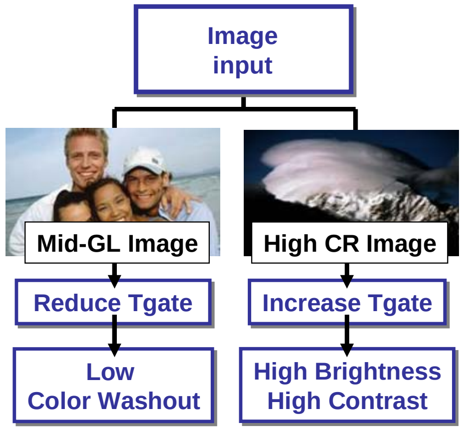
Fig. 4. The improved response time of LC rising curve.

3.3 Dynamic Off-axis Image

ART utilized a sub-TFT to control the V_{sub} for optimizing the color washout and response time. However, color washout and brightness are the two trade-off trends(less brightness has less color difference), as shown in the Fig. 5(a). With ART technology, the image quality in each frame can be real time optimized by simply adjust the gate pulse width(Tgate) of sub-TFT. As the flow chart illustrate in Fig. 5(b), both skin color and high contrast image can yield high performance for on- and off-axis image. This characteristic also widens the design and fabrication flexibility..



(a)



(b)

Fig. 5. (a) The curves of color shift and brightness, and (b) the simple flow chart of dynamic image adjustment by using ART.

3.4 Optimized Vcom (Flicker)

By using ISDO method, the flicker index of main-area, sub-area, and two-area-combined(total) are shown in Fig. 6. The optimized Vcom of each is 6.4V, 5.4V and 5.8V respectively. The separation of two-area optimized Vcom is 1V which was measured by ISDO method. At 5.8V Vcom setting, each area flickers was serious, but two-area-combined flicker was invisible. It shows that the two areas have similar flicker level but in totally opposite phase, which can not be detected by the traditional flicker measurement. ISDO method can verify each-area flicker status and furthermore help pixel design toward less optimized-Vcom separation. Thus the residual DC in both areas is reduced, and the image sticking performance can be improved.

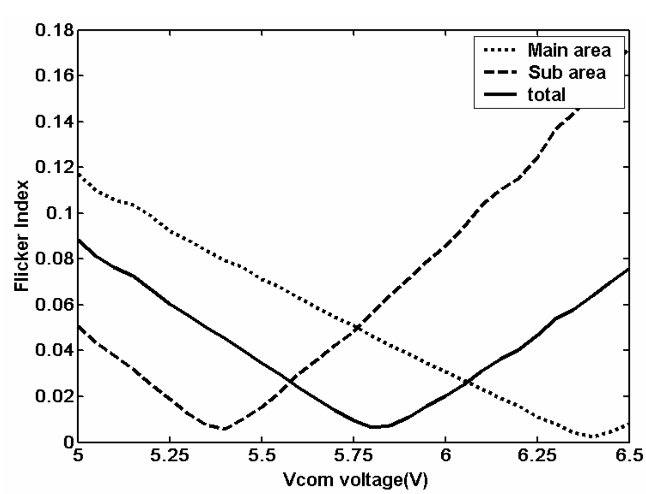


Fig. 6 Flicker index of each area versus Vcom voltage.

3.5 Products Implementation

A-MVA mode had already been implemented into the AUO's LCD-TV and moni-TV (large size monitor) products. It had been successfully proved the technology is a promising solution of advanced LCD-TV panels for mass-production.

4. Conclusions

A-MVA mode has double domains(8-domains) that are truly automatically generated with single source and gate line was proposed. A-MVA utilized Additional Refreshed Technology (ART) to enable the capabilities of not only color washout improvement but also the automatic self-overdriving for better response time. Additionally, according to various image properties, ART can real time optimizes the image performance by adjusting the gate pulse width. For the A-MVA mode, GRD value and ISDO method was also utilized to optimize the off-axis image and flicker when designing the pixel. A-MVA is one of the most applicable ways to be used in all sizes of LCDs, and has been already applied to AUO's LCD products.

5. References

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