Memory Reduction Method of Luminance Compensation Algorithm for Mobile AMOLED Display Applications

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Abstract-- A memory reduction method of luminance compensation algorithm using luminance sensor is proposed for high resolution mobile active matrix organic light emitting diode (AMOLED) display applications. The proposed method can be applied to AMOLED panels which have poor luminance uniformity even though compensation pixel circuit is used. Measurement results show that the deviation of luminance error is reduced from 18.1% to 3.8% when the proposed algorithm is applied to 5.3-inch AMOLED panel using threshold voltage compensation pixel structure.

I. INTRODUCTION

The luminance non-uniformity of active matrix organic light emitting diode (AMOLED) display due to electrical variation of polycrystalline silicon thin film transistors (TFTs) is main problem to achieve high image quality display [1]. Previously, pixel structures and driving methods to compensate electrical variation of driving TFTs have been reported [2-4], but compensation capability is reduced as the display resolution is increased because the row line time which is used for compensation phase is reduced as the resolution of panel is increased. To solve the problem of limited compensation time, the parameter extraction and data adjusting method using light sensor have been proposed [5]. This method assumed that the relation of luminance and data voltage of AMOLED pixel is quadratic [5], however drain current of driving TFT is not quadratic function thus luminance error will be increased due to the large difference between modeling and real characteristic in low gray levels.

To improve compensation capability, a new model equation between luminance and data voltage is required. However, accurate model increases complexity of calculation logic block for data modulation and required memory due to extended the number of parameters. To solve this problem, a new compensation algorithm is proposed to simplify calculation logic block and reduce required memory. The proposed algorithm is verified by 5.3-inch AMOLED display panel of 800×1280 resolution format.

II. PROPOSED DRIVING SYSTEM

The proposed compensation algorithm consists of two steps, which are parameter extraction with luminance sensing step and displaying step with data modulation for compensation. Fig. 1(a) and 1(b) show the block diagram of parameter extraction with luminance sensing step and displaying step using data modulation.

In the parameter extraction with luminance sensing step, same reference gray data is programmed to entire pixels and optical sensor measures the luminance of every pixels. The parameter extraction block receives pixel luminance data and reference gray data, and extracts parameters to characterize luminance-gray data relation of each pixel. The extracted parameters are stored to external memory. This step is required to be performed only one time because once extracted parameters are stored to non-volatile memory and they can be used in displaying step with data modulation.

In the displaying step with data modulation, calculation logic block receives original image data and the extracted parameters from external memory and computes compensated data. The data driver programs the compensated data to each pixel.

III. COMPENSATION ALGORITHM

During the parameter extraction with luminance sensing step, the luminance-gray data of AMOLED pixel is modeled as,

\[ L = \alpha (V_{data} - \beta)\gamma, \]  

where \( L \), \( V_{data} \), \( \alpha \), \( \beta \), and \( \gamma \) are output luminance, input gray level, slope factor, shift factor, and curvature factor of AMOLED pixel, respectively. In this model, \( \alpha \) depends on channel mobility of driving TFT and efficiency of OLED, and \( \beta \) depends on the threshold voltage of driving TFT. The parameter \( \gamma \) depends on exponent factor of saturation current of driving TFT and curvature of luminance-current relation of OLED, and gamma correction for human eye perception. Equation (1) is the general model of voltage programming current source (VPCS) type AMOLED pixels, thus the proposed algorithm can be applied to any VPCS AMOLED.
panel. To extract $\alpha$, $\beta$, and $\gamma$ parameters, more than 3 points of luminance of each pixel is measured, and nonlinear least square algorithm is used. The modulated data can be expressed as,

$$G_{\text{mod}} = \beta + \gamma \left( \frac{L_{\text{MAX}}}{\alpha} \frac{G_{\text{input}}}{255} \right),$$

(2)

where $G_{\text{mod}}$, $G_{\text{input}}$, and $L_{\text{MAX}}$ are compensated gray data, original input gray level, and maximum target luminance, respectively. Then, the luminance of compensated pixel ($L_{\text{mod}}$) can be expressed as,

$$L_{\text{mod}} = \alpha \left( \beta + \gamma \left( \frac{L_{\text{MAX}}}{\alpha} \frac{G_{\text{input}}}{255} \right) \right)^\gamma = L_{\text{MAX}} \left( \frac{G_{\text{input}}}{255} \right)^\gamma.$$

(3)

Equation (3) shows that the compensated luminance only depends on input gray level and maximum target luminance. The computation of (2) should be performed in calculation logic block as shown in Fig. 1(b) however the second term of (2) is hard to realize simple arithmetic operation. To accomplish this operation, high speed digital signal processor in calculation block is required, but it increases system cost and chip size. This disadvantage makes hard to apply the proposed method to mobile AMOLED applications.

To solve this problem, $\gamma$ parameter of every pixel is averaged then the second term of (2) can be realized in simple arithmetic operation and look-up-table. Fig. 2 shows the block diagram of calculation logic. However, averaged $\gamma$ increases fitting error between sensed luminance data and fitted luminance curve, (1), because $\alpha$ and $\beta$ parameters are optimized from raw $\gamma$ parameters. To reduce fitting error, the second fitting is performed with respect to $\alpha$ and $\beta$. Eventually, the required memory is (the number of pixels) $\times 3$ (red, green, and blue) $\times 2$ ($\alpha$ and $\beta$) $\times 8$ (bit depth of gray scale).

Therefore, required external memory to store pixel parameters can be reduced and simple arithmetic operation is required by using averaged $\gamma$ parameter.

IV. MEASUREMENT RESULTS

The proposed luminance compensation algorithm is applied to 5.3-inch 800×1280 resolution format AMOLED display using polycrystalline silicon TFT backplane. The fabricated AMOLED panel uses threshold voltage compensation pixel structure [4]. The luminance sensing for parameter extraction in Fig. 1(a) is performed using 6 points of luminance intensity. The computation for nonlinear least square algorithm and generation of look-up-table are executed using a PC.

Fig. 2. block diagram of calculation logic.

Fig. 3. Measurement result (a) without compensation method, (b) with compensation method of luminance in middle gray level (127 gray), and (c) luminance error on 400th column line.

Fig. 3(a), (b), and (c) show measured results of AMOLED panel without the proposed algorithm, with the proposed method, and luminance error on 400th column line in 127 gray level using self-compensation pixel circuits, respectively. The measured results show that the luminance error deviation is 18.1% without the proposed algorithm, and it is reduced to 3.8% with applying the proposed algorithm.

V. CONCLUSION

In this paper, a compensation algorithm to improve luminance uniformity of AMOLED display by using optical sensor and data modulation logic is proposed. The proposed algorithm can reduce required external memory size and simplify calculation logic block. Experimental results show that the deviation of luminance error is achieved to 3.8% whereas the luminance error deviation 18.1% without the proposed method in 127 gray level using the panel with self-compensation pixel circuit.

REFERENCES