Image Contrast Enhancement for TFT-LCDs

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Abstract

A novel image contrast enhancement (ICE) circuit was proposed by modulating the reference voltages of the source driver circuit in liquid-crystal displays (LCDs). The adjustment of reference voltages is achieved immediately by applying external adjustment codes, which may be generated in accordance with the video data distribution on image displays and the liquid crystal materials, and leads to the change of gamma characteristic of LCD's and better image quality.

Keywords: contrast enhancement, reference voltage, driving circuit, TFT-LCDs.

摘要

本論文提出一個可增強影像對比的電路。電路的原理是以即時的影像資料統計產生的控制碼來調變液晶顯示器的灰階參考電壓值，進而改變顯示器的伽瑪曲線，可增強影像對比，得到品質較佳的影像。

關鍵詞：增強對比，參考電壓，驅動電路，液晶顯示器。

1. INTRODUCTION

TFT-LCD's are becoming suitable display devices for digital TVs due to their light, slim design, low power consumption, and large-size capability. Compared with cathode-ray tube (CRT) display, LCD devices have problems of slow response and blurred pictures especially for darker and/or brighter image patterns.

For an ideal image display, the input pixel value and the output pixel brightness (or transmittance) should be linearly related. However, for a LCD panel, the image acquisition and image display systems suffer from the photometric distortion in light sensitivity or brightness of an image. Hence, the brightness is not linearly related to the input pixel voltage. To fit this problem, the gamma correction is needed [1-8]. The gamma curve could be expressed as following formula: $Y = X^{\frac{1}{\gamma}}$

The characteristic of the gamma curve could be controlled by varying γ value as shown in figure 1. Due to the nonlinearity of the transmittance-voltage (T-V) curve, LCD panels need appropriate gamma correction to compensate this effect. Figure 2 shows the T-V curve (solid line, labeled as '1') algebraically representing the light transmittance of liquid crystals varied with the voltage applied to the liquid crystal. The gradation of contrast of an image may be determined using the straight line portion at region II of the T-V curve [2-3]. The image quality becomes better with an increase in the gradation number. The ratio of the light transmittance to the applied voltage does not remain constant; rather it varies with the applied voltage especially at the region I and III of the T-V curve as shown in figure 2.

The characteristic of the gamma curve must be corrected into linear relationship, as shown by the dotted line '2' in figure 1 in order to make the brightness of the image smooth and improved quality. If most video data exist in a certain range, the image contrast will be of inferior quality. The principle of the proposed circuit is to adjust the reference voltages based on the video data distribution of each frame to make the slope of gamma curve steeper, thus achieve the enhancement of the image contrast [9]

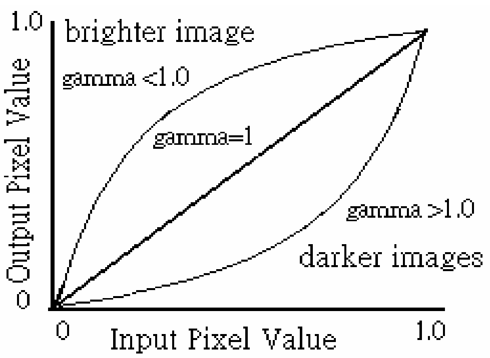

Figure 1 Gamma curve of displays

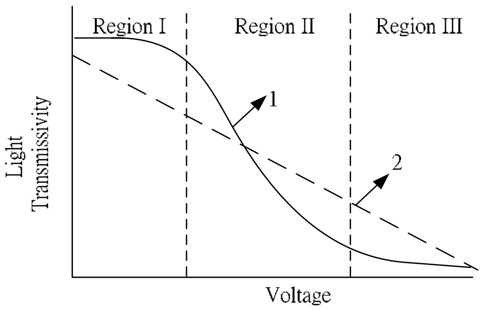

Figure 2 Transmittance-voltage characteristic of normally-white LCD's

2. SOURCE DRIVER ARCHITECTURE

The source driver circuit of TFT-LCDs with the proposed novel image contrast enhancement circuit was shown in figure 3. The 6-bit RGB video data were transmitted from a timing controller to the sample registers which latch the data sequentially as receiving the pulse signal from the shift registers. When each 6-bit data from first sub-pixel through the last sub-pixel had been latched in sample registers, the data were then sent through hold registers to digital-to-analog converter (DAC). The DAC converted the 6-bit digital data to a corresponding analog voltage value of 64 gray level voltages and output it to a data line on an LCD panel through an output buffer. The switches after output buffers control the positive or negative polarity of output voltages for line-inversion or dot-inversion TFT-LCDs.

3. REFERENCE VOLTAGE ADJUSTMENT DEVICES

The gray level voltage generation circuit was shown in figure 4. The reference voltage generator of a conventional TFT-LCD was shown in fig. 4(a) and consisted of a resistor-string voltage divider. There is no way to adjust the reference voltages and the gamma curve of LCDs after the R-string voltage divider. To overcome this problem, the proposed ICE circuit as shown in fig. 4(b) can easily change the reference voltages frame by frame according to external adjustment signals. The proposed image contrast enhancement circuit was as shown in figure 5. A multi-channel digital-to-analog converter that composes of resistor elements R0 through R7 has a resistance ratio for gamma correction and generates gamma corrected intermediate voltages (Vref7~Vref1) on the basis of voltages across input terminals V0 and V64. Each reference voltage adjustment device can increase or decrease the intermediate voltages independently on the basis of adjustment signals from an external video data statistical circuit.

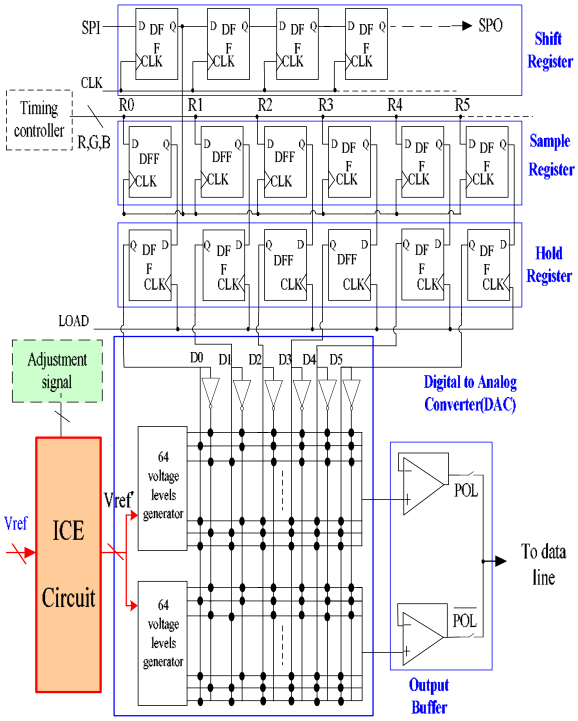

Figure 3 Thel source driver circuit with the ICE circuit.

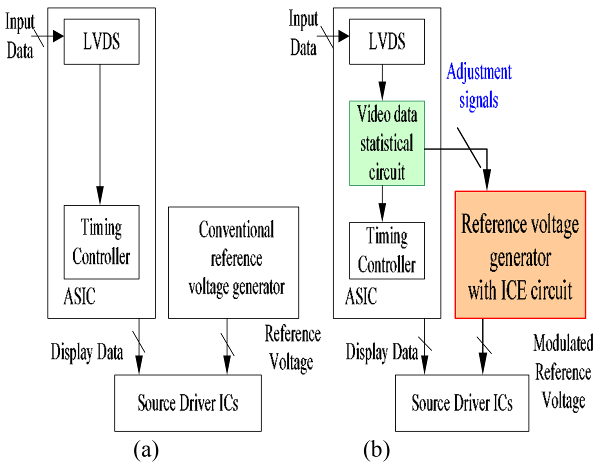

Figure 4 Gray level voltage generation circuit (a) conventional LCD (b) LCD with ICE method.

The proposed reference voltage adjustment device was shown in figure 6. The adjustment device is consisted of an adjustable voltage converter, an adjustable voltage inverter, two multiplexer and an analog voltage adder. Applying the multi-bit digital adjustment data coded by the two's-complement representation, the switches (S1~S4) are controlled to be turned on or off, respectively. The adjustment codes S1 and S2 determined the magnitude of modified Vref value and the S3 controlled Vref variation upward or downward. The output voltage of the multiplexer controlled by S3 is $Vf = V_1 \times (1 + \frac{R_n}{R})$ and $Vf = V_1 \times (-\frac{R_m}{R})$ for positive and negative variation of Vref, respectively, where n and m is ranging from 1 to 4 and 5 to 8, respectively. The adjustment signal S4 determined the function of the analog voltage adder, which works as either a source follower or a voltage adder. The former passes the Vref to output node when S4 is 'low' and the later adds the delta Vref (i.e. Vf) selected by S3 to Vref when S4 is 'high'. The magnitude of the output voltage, Vref', is determined by these adjustment signals (S1~S4) and the R_n (or R_m) values. In addition, the R_n (or R_m) values for different Vref, i.e. Vref1~Vref7, as shown in Fig. 5, will be designed to different values so that a smooth gamma curve can be achieved as shown in Fig. 1.

The adjustment codes may be generated in accordance with the video data distribution of image for every frame and the T-V curve of liquid crystal materials. Therefore, the gamma characteristic of LCD's can be simply changed. The modulation of gamma characteristic based on 4-bit adjustment codes enables the execution of adjustment of the gamma correction value in 15 steps ranging from -7 to +7.

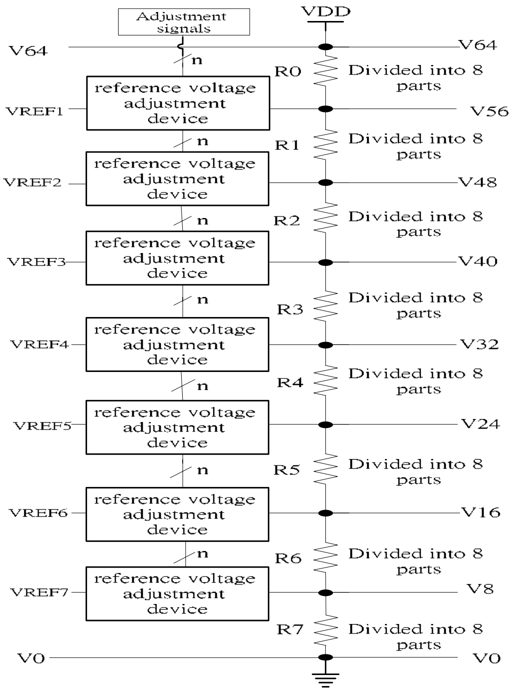

Figure 5 The proposed image contrast enhancement (ICE) circuit.

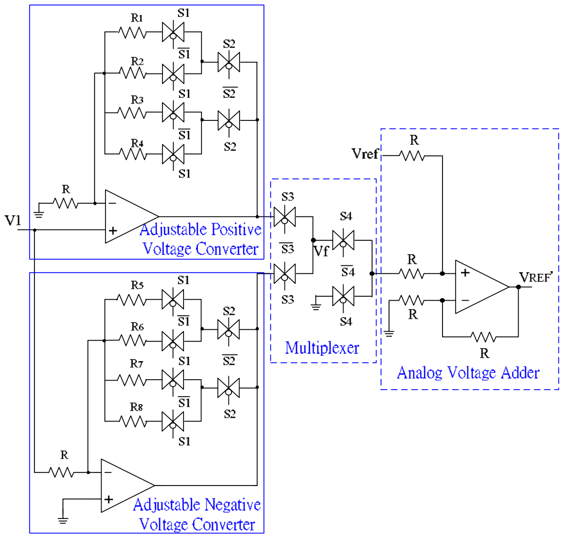

Figure 6 The proposed reference voltage adjustment device.

4. SIMULATION RESULTS

The proposed ICE circuit combined with a source driver circuit of TFT-LCDs, shown in figure 3, was simulated by H-Spice. A set of reference voltages (Vref1~Vref7) that serves as an original reference are ranging from 0 to 5 V. The adjustment codes were arranged that makes the output voltages of buffers varying form the most negative value to the most positive one.

The 64 gray level output voltages of source driver circuits were shown in figure 7. The horizontal axis 'simulation time' from 0 to 640 usec means the 64 gray levels of LCDs. In the figure, line 'a' indicates steeper gamma curve in the low voltage group (i.e. dark image for normally black panel). Line 'c' indicates steeper gamma curve in the high voltage group (i.e. bright image for normally black panel). Therefore, the image contrast was enhanced with an increase in the gradation number due to steeper gamma curve.

5. CONCLUSION

A novel image contrast enhancement (ICE) circuit by controlling the reference voltages and the gamma curve in TFT-LCDs was proposed. The adjustment of reference voltages is achieved immediately by applying external adjustment codes. The proposed method is believed to improve the image quality and will be applicable to TFT-LCD panels, especially for LCD-TVs.

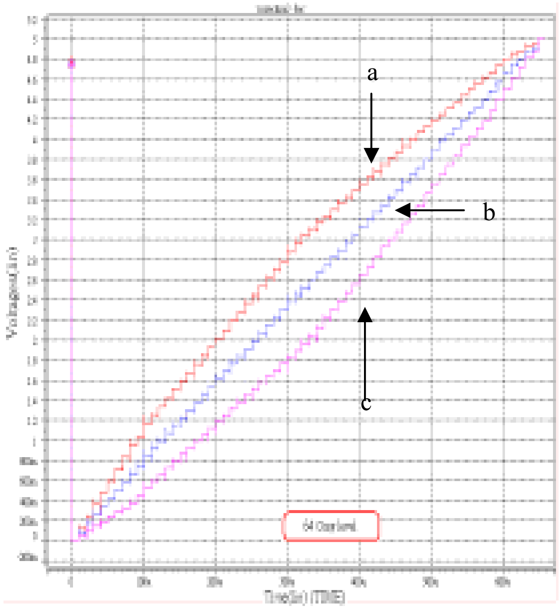

Figure 7 Output voltages of DAC with ICE circuit (a)for dark image case (b)for normal case (c)for bright image case

6. ACKNOWLEDGEMENT

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