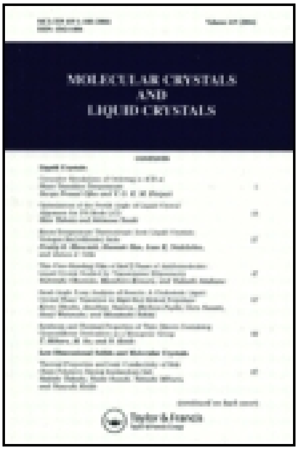

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A Full-Color Video Rate FLC Display Based on Time Domain Color Switching with a TFT Array

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A Full-Color Video Rate FLC Display Based on Time Domain Color Switching with a TFT Array

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This document introduces a full-color video rate FLC display which is based on time domain color switching with an amorphous Si TFT array. Research on particular polarization switching properties provided us with the technology for quick switching FLCs by using amorphous silicon TFTs. We created a prototype, and confirmed that it provided gray scale, short response time, high color purity, color balance adjustment, and a wide viewing angle. Our prototype demonstrated that it was possible to create a full-color video rate display based on this technology.

Keywords: Field sequential color LCD; SSFLCD; LED backlight

INTRODUCTION

For color liquid crystal displays, STN and TFT-TN are the technologies that are most widely used today. Unfortunately, conventional LCDs, that are based on these technologies, have some weak points: They provide only slow response, and support only a narrow viewing angle. Their color purity is low and the white balance can't be adjusted. Besides, they don't provide low manufacturing costs, either.

We developed a color liquid crystal display with short response time, wide viewing angle, superior color purity, and adjustable white balance, so as to overcome the problems of conventional LCDs.

This display synchronizes the monochrome color emission of red or green or blue light with the switching of the liquid crystal display. For displaying sequential colors[1,2], a liquid crystal display needs to provide high-speed response.

We tried to use a surface stabilized ferroelectric liquid crystal[3] (SSFLC) display to produce a field sequential color LCD (FSCLCD). The image quality of the SSFLC display is characterized by high contrast ratio with a wide viewing angle and fast switching time, which is in the order of 100 μ s. We selected a light emitting diode (LED) backlight, so that it would be possible to create the backlight by switching between red or green or blue light.

PRINCIPLE AND CHARACTERISTICS OF THE FSCLCD

The structure of the FSCLCD is shown in Figure 1. The LED backlight we used combines the LED array with light guide plate and diffusing plate. Our FSCLCD consists of this LED backlight and ferroelectric liquid crystal display (FLCD) with a TFT array.

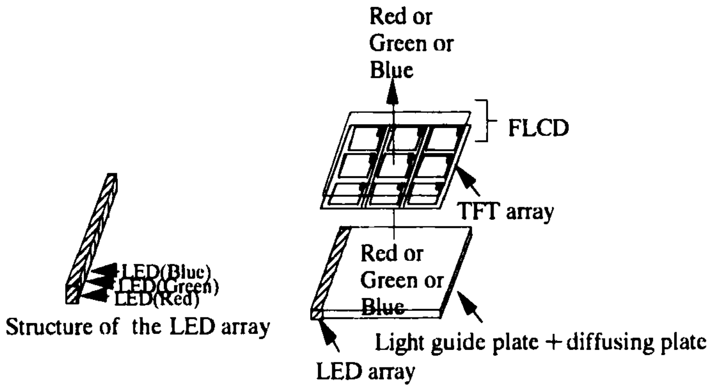

FIGURE 1 Structure of the FSCLCD.

Figure 2 shows the general principle used for the FSCLCD. Each frame is divided into three subframes, and these subframes contain the data for red or green or blue picture layers, respectively. Monochrome light of red or green or blue is emitted continuously in intervals of 1/180 seconds. The emission of monochrome light of red or green or blue and the switching of the FLCD occurs simultaneously. Within each sub frame, write scanning and erase scanning are performed, so that FSCLCD requires a scanning time for less than 5 μ s a line.

The viewer perceives the picture that is composed of these components.

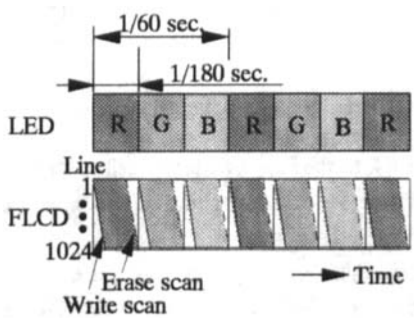

FIGURE 2 Driving scheme of FSCLCD.

By using field sequential color together with an LED backlight, the following display characteristics are obtained.

The FSCLCD doesn't require color filters. The number of data drivers is only one third the number of drivers required in conventional LCDs. Accordingly, it is possible to reduce manufacturing costs. As we are using an LED backlight, the adjustment of the white balance is easy, and high color purity is provided. Furthermore, a high resolution display can be produced easily, as FSCLCDs do not require to divide a pixel into three sub pixels.

Finally, FLCDs have a very short response time and support a wide viewing angle.

EXPERIMENTAL

Our premise in developing the FSCLCD was that we would use a TFT array to drive the FLC. We set up an experiment for testing how to drive the FLC using a TFT array as follows:

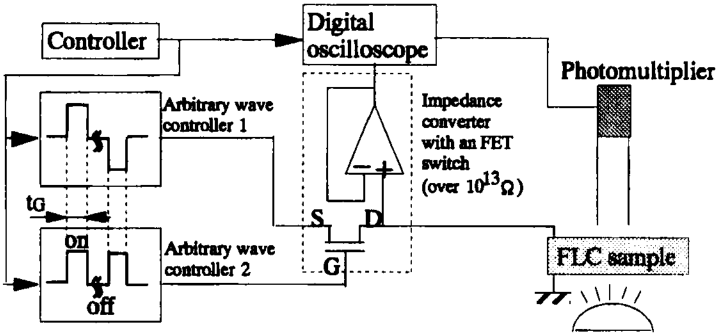

FIGURE 3 Measuring system.

We connected an FET to the FLC evaluation cell as shown in figure 3, and provided the input voltage by FET switching. We measured the intensity of the light that was transmitted at that time.

The evaluation cell that was used in this experiment used a poly-amideimide alignment layer. This alignment layer provides a pretilt of one degree or less. We prepared an empty anti-parallel rubbing cell with a gap of 1.8 μ m. The electrode area was 1.77 cm^2. We then injected a naphthalene-tolane system liquid crystal, which showed almost ideal bookshelf layer structure[4], into the empty cell, so as to create the evaluation cell. We measured how the transmittance depended on the gate on time, t_G, of the FET and on the applied voltage.

GATE ON TIME AGAINST TRANSMITTANCE

Figure 4 shows the gate on time, t_G, of the FET against transmittance characteristics for an applied voltage of 5V.

The transmittance became 100 % for a prolonged gate on time of 350 μ s. For a gate on time in the range of 4-20 μ s, the transmittance was constant. The response time of the liquid crystal for the 5V used in the experiment was approximately 300 μ s. Furthermore, the time it took liquid crystal to react to an increased voltage was 10-20 μ s. We concluded that this phenomenon occurred because of spontaneous polarization (Ps) switching[3].

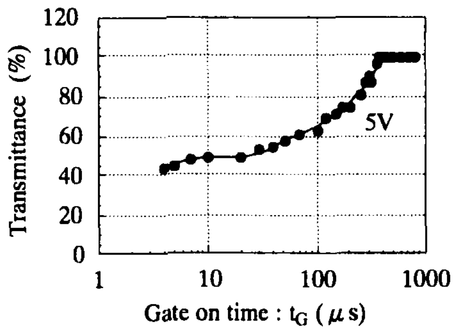

FIGURE 4 Dependence of transmittance on the gate on time.

In other words, the quantity of the charge that is saved in the cell is not influenced by Ps switching if the gate on time is short. However, Ps switching influences the quantity of the charge if the gate on time is long.

As shown in figure 5, constant transmittance was observed when we allowed the applied voltage to change.

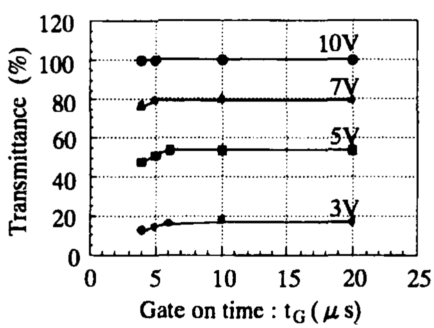

FIGURE 5 Dependence of transmittance on the gate on time for various applied voltages.

From these results, it was evident that a driver with a short gate on time is necessary to make a field sequential color LCD possible.

Figure 6 shows the voltage-transmittance characteristics of the FLCD. The gate on time is 5 μ s. Figure 6 shows the transmittance that corresponds to the applied voltage. According to these results supporting gray scale should be possible as well.

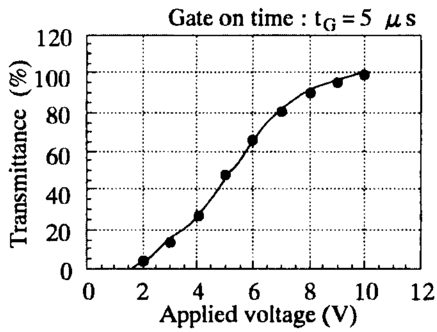

FIGURE 6 T-V characteristics.

PROTOTYPE

Based on the results of our study, we created a prototype FSCLCD. Figure 7 shows this prototype. The characteristic properties of this prototype as based on VGA specifications are summarized in Table 1.

We set the display area to 3.2 inches. We obtained a contrast ratio of over 50:1 and 190 cd/m^2 of screen brightness. Response time was 300 μ s.

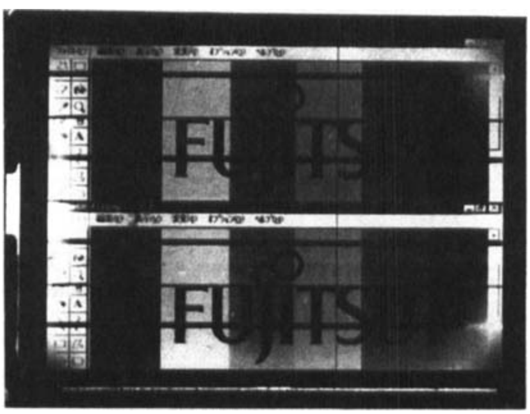

FIGURE 7 Photograph of the prototype.
See color plate I at the back of this issue.

Table 1 Characteristics of the prototype

Number of pixels (dots)	640 × 480 (VGA)
Dot pitch (mm)	0.10 × 0.10
Display area (mm)	64 × 48 (3.2 in.)
Colors	512
Contrast ratio	50:1
Response time (μ s)	300
Screen brightness (cd/m^2)	190 (white)
Viewing angle (deg.) (Contrast ratio > 10:1)	±70

IMAGE CHROMATICITY AND WHITE BALANCE

We examined image chromaticity and the change in white balance by adjusting the electric current of the driver of the red or green or blue LED of the Prototype.

Figure 8 shows the chromaticity of the prototype. High color purity was achieved that was almost equal to the purity of NTSC.

Figure 9 shows the chromaticity of the white image after adjusting the electric current of the red or green or blue LED driver. The numbers in the figure denote the ratio of the electric current for the driver compared to the current at the starting point of the adjustment. Corresponding to the electric current of the LED drivers of red or green or blue, the chromaticity of the white image changed. This demonstrates that it is possible to adjust the white balance by this means.

CONCLUDING REMARK

We created a field sequential color LCD which used a FLCD, a TFT drive and LED backlight. We established that it provided gray scale, high responsiveness, high color purity, color balance adjustment, and high image quality.

We built a 3.2-inch field sequential color LCD using a ferroelectric liquid crystal display that meets VGA specifications. Our prototype demonstrated that creating a full-color video rate display with this technology was possible.

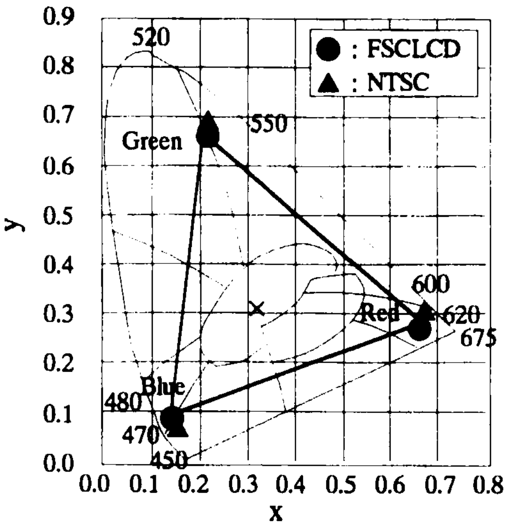

FIGURE 8 Chromaticity of the prototype.

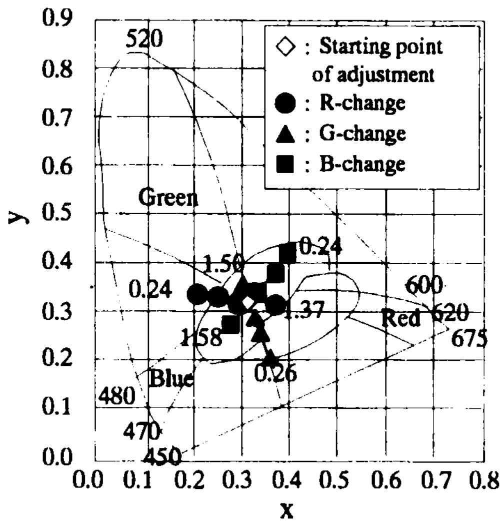

FIGURE 9 Chromaticity of the white image after adjusting the electric current of the red or green or blue LED driver.

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