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An LCD for the multimedia network age: Polymer stabilized FLCD

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Abstract. Liquid crystal displays (LCDs) will be classified into miniature displays, reflective type, projection type, direct view type, and holography type. All of these LCDs will be widely utilized in the coming multimedia network era. Along with this trend, in the first part of this paper we will discuss the social background of this research. We will place an emphasis on a polymer stabilized (PS) FLCD that is featured by fast response speed (40 microseconds), high contrast (230 : 1) with grayscale, wide viewing angle, and high resolution (400 lp/mm). The PS-FLCD will be promising technology for displaying a moving video image in the multimedia network era.

Keywords. Field sequential; full color; LCD; FLC; polymer stabilized FLCD.

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1. Introduction

In this paper, first we will discuss the current social background for LCD technology. We will do so by focusing on the power consumption of computers using LCDs and by projecting the future trend of information displays in the multimedia network era that will be realized by installing optical fiber network to every home, and further, by discussing ergonomics of information displays. In Japan, the so called 'Fiber to the Home Project' is already scheduled; and it will be completed in 2004. At this stage, it is necessary to develop an LCD that is capable of displaying moving video images with fatigue free viewing: the best data of the response time of the current LCDs using nematic LC is 2 ms, and therefore the frame rate is limited. We have succeeded in fabricating a polymer stabilized ferroelectric liquid crystal display (PS-FLCD) that exhibits a high contrast ratio (230 : 1) as it is free of zig-zag defects and has fast response (40 microseconds). We will discuss and demonstrate how our PS-FLCD is useful for full color video image displays using field sequential addressing technique at a high frame rate.

2. Social background for LCD technology

First, the energy consumptions, which are evaluated by CO_2 gas emission, of a computer with LCD and that with CRT are compared in figure 1. This life cycle assessment was done by a research group of NEC [1]. A computer with CRT consumes about three times larger energy compared to that with LCD in its entire life. We have thus a good reason for conducting further R and D on LCDs.

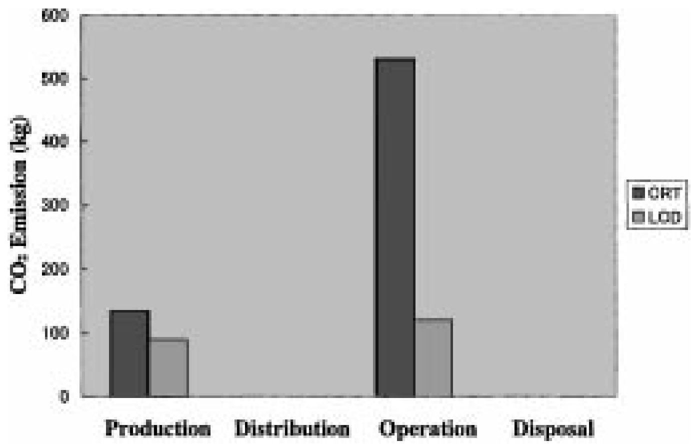

Figure 1. A comparison of the energy consumption expressed by the equivalent CO_2 exhaustion for computers with CRT and LCD (NEC).

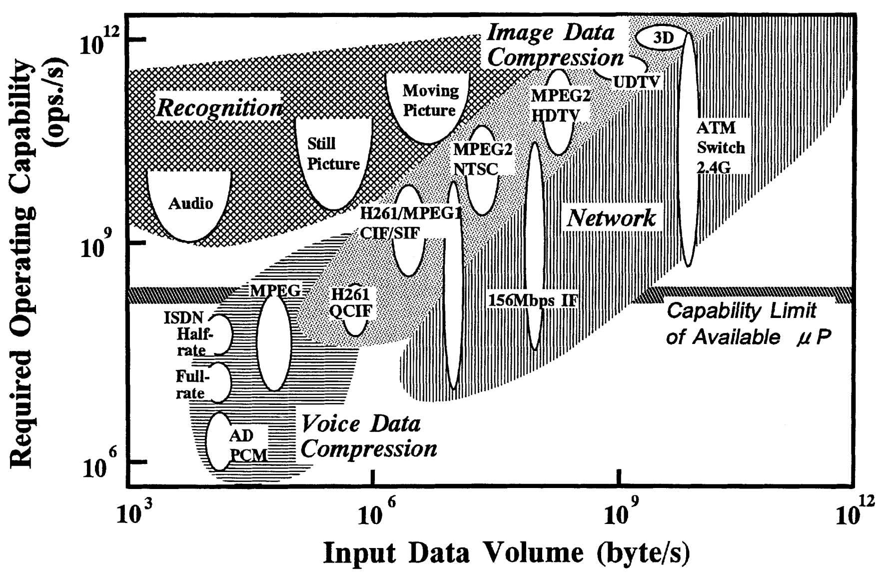

Figure 2. Operating capability of electronic systems in the multimedia digital network era (NTT).

Now, we will try to project the future trends in electronics. Figure 2 shows a result of the investigations done by a research group of NTT [2]; a digital TV with NTSC and MPEG2 specifications and HDTV need the information input volume of 10^7 bytes/s and 10^8 bytes/s, respectively. At the same time, 10^2 to 10^3 times improvement of the capability of the current microprocessor system is required. These scenorios will be realised by 2004 when the Fiber to the Home Project will start functioning.

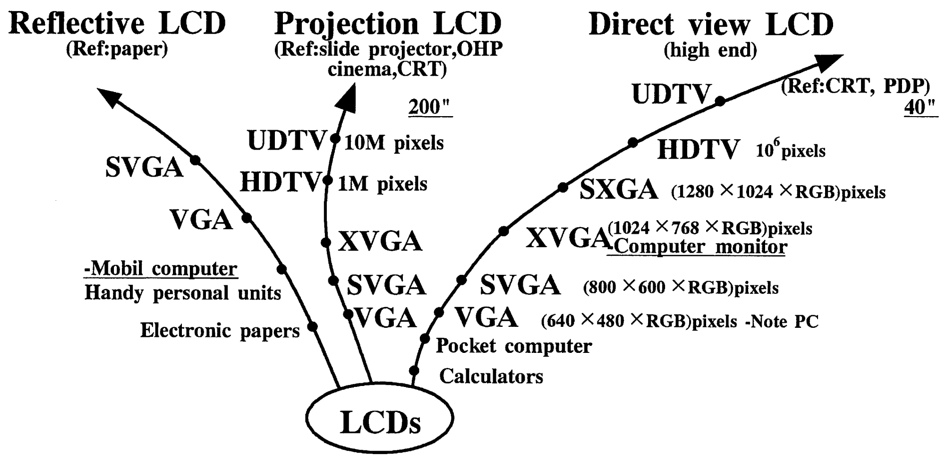

Figure 3. Development of LCD technology in terms of information contents and display size.

Regarding the fatigue of eyes and brain of a person who uses an electronic display, it is reported that the higher the frame rate the lower the fatigue. Therefore it is necessary to explore a new display technology for a high frame rate of more than 60 Hz.

3. LCD technology in the near future

Figure 3 illustrates the development of LCD technology in terms of information content and display size in the three categories of LCD technology. In the multimedia network era, all those LCDs will be utilized. Other important LCD technologies, which are not shown on this figure, are miniature LCDs and moving holography using LCD technology. We emphasise on PS-FLCD as a key device for these various applications.

4. Principle of field sequential color LCD

The techniques of color liquid crystal displays can be classified into additive or subtractive color formations, and further the former method comprises either spatially additive or temporally additive schemes. The principle of field sequential color (FSC) displays is based on the temporally additive mode. In comparison with conventional color LCDs, which use color filters, FSC-LCDs have several potential advantages, such as high luminance, low power consumption, high resolution, and simplicity in the fabrication since no color filters are used and also simplicity in the driving circuit. So far, with the aim of exploring the possibility of realising FSC-LCDs, several research groups have conducted investigations and two types of results have been published: in the first type, monochrome CRTs are converted into a color display using color LCD panels that are not in a matrix format [3–6] and in the second type, RGB color backlights are turned on sequentially and twisted nematic (TN) LCD, FLCD or OCB-LCD is used as a matrix optical shutter [7–10].

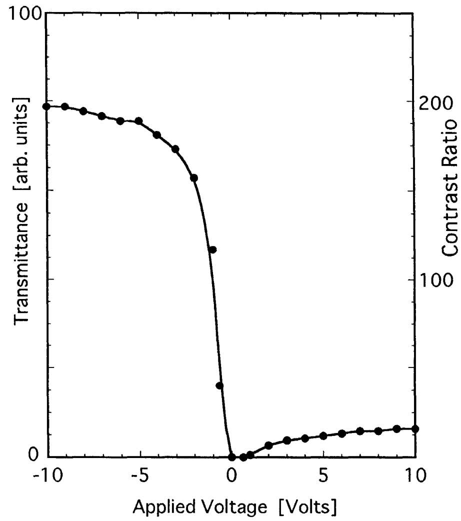

Figure 4. An example of the T-V characterstic curve of the PS-FLCD cell.

FLCDs are known to be a favorable medium for FSC-LCD since FLCDs have fast response times of several tens or hundreds of microseconds [7, 8, 9, 11].

In a previous paper the authors' research group reported a polymer stabilized ferroelectric liquid crystal display (PS-FLCD) [11] that exhibits high contrast ratio (230 : 1) with thresholdless monostability, continuous grayscale capability, and high speed response ($\tau = 40$ microseconds). We had the idea of exploring the possibility of FSC-LCD using our PS-FLCD together with a 2-D array of RGB LEDs as modulated back light. We fabricated an experimental FSC-LCD having 8×8 matrix format and actually we succeeded in demonstrating homogeneous colors, grayshaded colors, and moving color bars. The frame rate chosen in this experiment was 330 Hz for a preliminary evaluation of the developed FSC-LCD; as a result no smear was observed for moving color bars with the speed of 8 cm/sec.

Figure 4 shows an example of the characteristics of transmittance vs. applied voltage of the PS-FLCD cell. The transmittance can be controlled smoothly by changing the magnitude and polarity of applied voltages using the monostability of the device. A matrix PS-FLCD cell is illuminated uniformly with a backlight system that emits red, green, and blue colors sequentially, and PS-FLCD, which is an optical shutter matrix, is driven by applying synchronized signal or data voltages with the sequence of the backlight. Figure 5 shows the whole system concept of our FSC-LCD.

Figure 6 illustrates the actual timing chart of the FSC-LCD using our PS-FLCD together with the EO characteristics of PS-FLC cell, where a set of RGB frames is shown. During the period when the red light is turned on, the PS-FLC cell is scanned from the 1st line to the *n*th line by applying signal or data voltages with a negative polarity in this particular example; just after finishing the scanning of the *n*th line, erasing period starts by applying voltages with a positive polarity, where voltages with different polarities must be equal in order to avoid the accumulation of extra charges. The green and blue fields which follow are scanned and driven in the same way as the red field. Unlike other

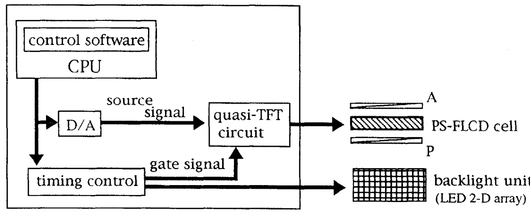

Figure 5. The whole system concept of our FSC-LCD.

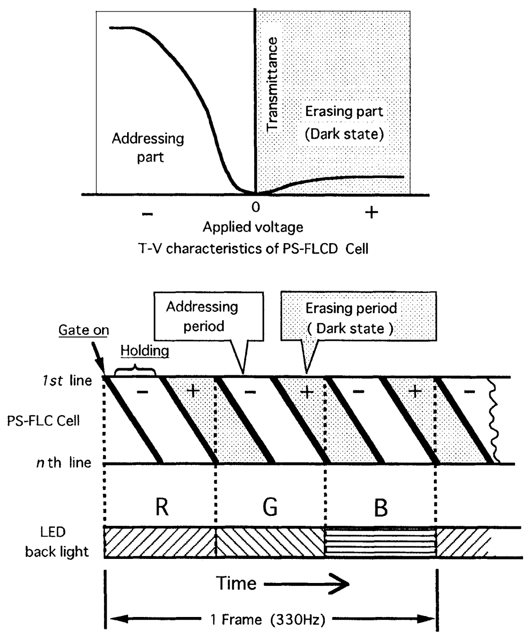

Figure 6. The actual timing chart of the FSC-LCD using PS-FLCD.

cases of FSC-LCD [9, 10] it is unnecessary to provide an extra erasing period in our system owing to a unique and favourable characteristic of our PS-FLCD.

5. Experimental

The inner substrate surfaces of the cell are coated with polymide films RN-1199 (Nissan Chem. Ind.) which produces a defect free C2 uniform alignment of FLC. The polymide films were spin coated and after the heat treatment at 250°C for 1 hour, parallel rubbing was done and a cell with 2 micrometers cell gap was constructed and then an FLC material FELIX-M4851/100 (Hoechst) doped with 2 wt% photocurable side-chain mesogenic monomer UCL-001 (DIC) was injected into the cell at the temperature corresponding to the isotropic phase. Then the photo-curing of FLC medium was carried out with an UV light source (365 nm, 2 mW/cm^2) for 60 sec at room temperature when the LC medium is in the SmC* phase, under the application of dc voltage (15 V). We fabricated a PS-FLC

Figure 7. Examples of homogeneous color images displayed on our FSC-LCD using PS-FLCD.

Figure 8. Examples of the grayscale color images and color bars displayed on our FSC-LCD using PS-FLCD.

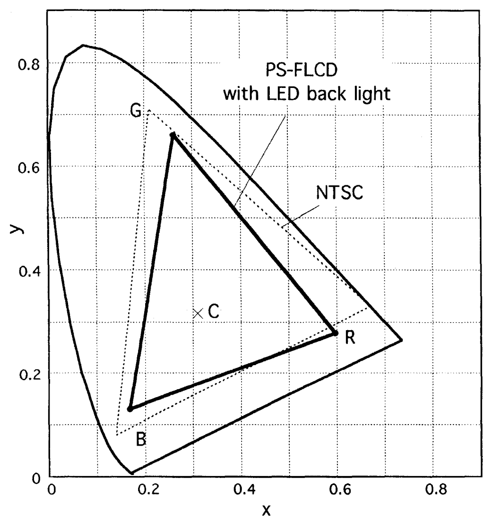

Figure 9. Color gamut and the white point of our FSC-LCD system on the 1931 x–y color coordinates.

cell having 8 × 8 matrix format with the area of 3 cm × 3 cm. The backlight system used in this experiment comprises a 2-D array of R, G, and B LEDs (supplied from Nichia Chem. Ind.). Actual demonstration was done by constructing 8 bars from 8 × 8 matrix, where each bar is driven with an FET driver. In this study, the frame rate is 330Hz for a preliminary evaluation of our FSC-LCD even though the frame rate of the conventional display systems is 60 Hz. Several display patterns are demonstrated on the 8 × 8 matrix PS-FLCD cell, such as homogeneous eight colors, eight colors with grayscale, still color bars and moving color bars with a moving speed of 8 cm/sec.

6. Results and discussion

Figures 7 and 8 show some examples of homogeneous color images, color images with grayscales, each color, and the color bars. No smear is observed on a moving bar having a lateral moving speed of 8 cm/sec. Figure 9 shows the color gamut obtained and the white point of our FSC-LCD on the 1931 x-y color coordinates. A fairly good color performance is obtained with the FSC-LCD developed.

Basically, our PS-FLCD must be driven in a form of active matrix using 2-D array of TFTs or TFDs. Fabrication of a prototype of the TFT driven FSC-LCD is now under way and the results will be published elsewhere.

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