Development of Fast Response Time (16msec) in IPS Mode

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Abstract

To be able to show moving images without visual problems like blurring and tailing, the response time of liquid crystal display (LCDs) must be improved. In this paper we will discuss our progress in improving the response time by optimizing the cell configuration and the use of new liquid crystal mixtures. A 20.1-inch diagonal UXGA IPS TFT-LCD has been developed having a response time as fast as 1-frame time (16msec) for white-black operation and less than 16msec in all gray levels without applying ODC (Over Driving Circuit). This is very important because one of the technology to reduce motion blurring, the use of scanning backlight is conditioned by 16msec for all grays. The excellent gray-to-gray response can be explained by virtue of fundamental characteristics of S-IPS mode and makes a good contrast with the results of VA mode.

Introduction

The market of large screen LCDs has been growing, starting with applications such as Note PC, followed by PC Monitor. Recently, the LCD-TV market is expected to be promising. Technologies for cost reduction as well as for display quality improvements have been studied extensively.

From the viewpoint of the TV application, improvements of these three characteristics are necessary to accelerate the market growth. .

-. Viewing angle
-. Brightness
-. Response time

Development of display modes has focused on improvement of viewing angle characteristics such as TN with optical compensation films, multi-domain TN, multi-domain VA and super IPS mode. We have been using the super IPS technology for all kinds of applications because of its marvelous viewing angle properties. In case of response time, many LCD makers have been trying to reduce the response time of their LCD panels. Much progress has been made in TN LCD products. But it is relatively difficult to get high response time in IPS products because of its complicated structure. We challenged to make an IPS LCD with a response time less than 16msec, which corresponds to one frame time.

Development of 16ms 20.1" UXGA

We have developed a 20.1-inch diagonal UXGA TFT-LCD. The specifications are shown in Table 1. This LCD has good performance with respect to response time of 16ms. We applied super IPS mode to this LCD. To explain how we have dealt with the response time issue, the formula of response time for IPS cell is shown below: [1]

$$Tr = \frac{\gamma_1}{\varepsilon_0 \Delta \varepsilon \frac{V^2}{l^2} - \frac{\pi^2 K_2}{d^2}} \qquad Tf = \frac{\gamma_1 d^2}{K_2 \pi^2}$$

where γ1 is the rotational viscosity of the LC mixture , which is a most influential parameter of response time and d is the cell gap.

Table 1: Display specification of the 20" UXGA LCD

Item	Specification
Display size (diagonal)	510.54mm
Display pixel (Hor.×Ver.)	1600×1200
Pixel pitch	0.255mm×0.255mm
Number of colors	16.7M (8bit/color)
Color Gamut	72% NTSC
Color coordinate (White)	0.313, 0.329
Contrast ratio	> 400 : 1
Brightness	250cd/m²
Response time	16ms
Response time (intermediate gray scale)	≤ 16ms (*1)
Viewing angle (CR ≥ 10˝)	Ver. ≥ 176 ° Hor. ≥ 176 °

(*1) without ODC

The dielectric constant Δε and the elastic constant K2 have an effect only during the on time and off time, respectively. Increasing the elastic constant K2 is effective not only in decreasing the response time, but also in increasing the operating voltage. The cell gap d and the electrode distance l are also highly influential factors. Based on the concept that the response time is in proportion to cell gap d, we attempted reduction of the cell gap d by applying patterned spacer technology .

However an increase of the operation voltage related to reduction of the cell gap was observed in the following equation and Figure 1. [2,3]

$$V_{th} = \frac{\pi l}{d}\sqrt{\frac{K_2}{\Delta \varepsilon \, \varepsilon_0}}$$

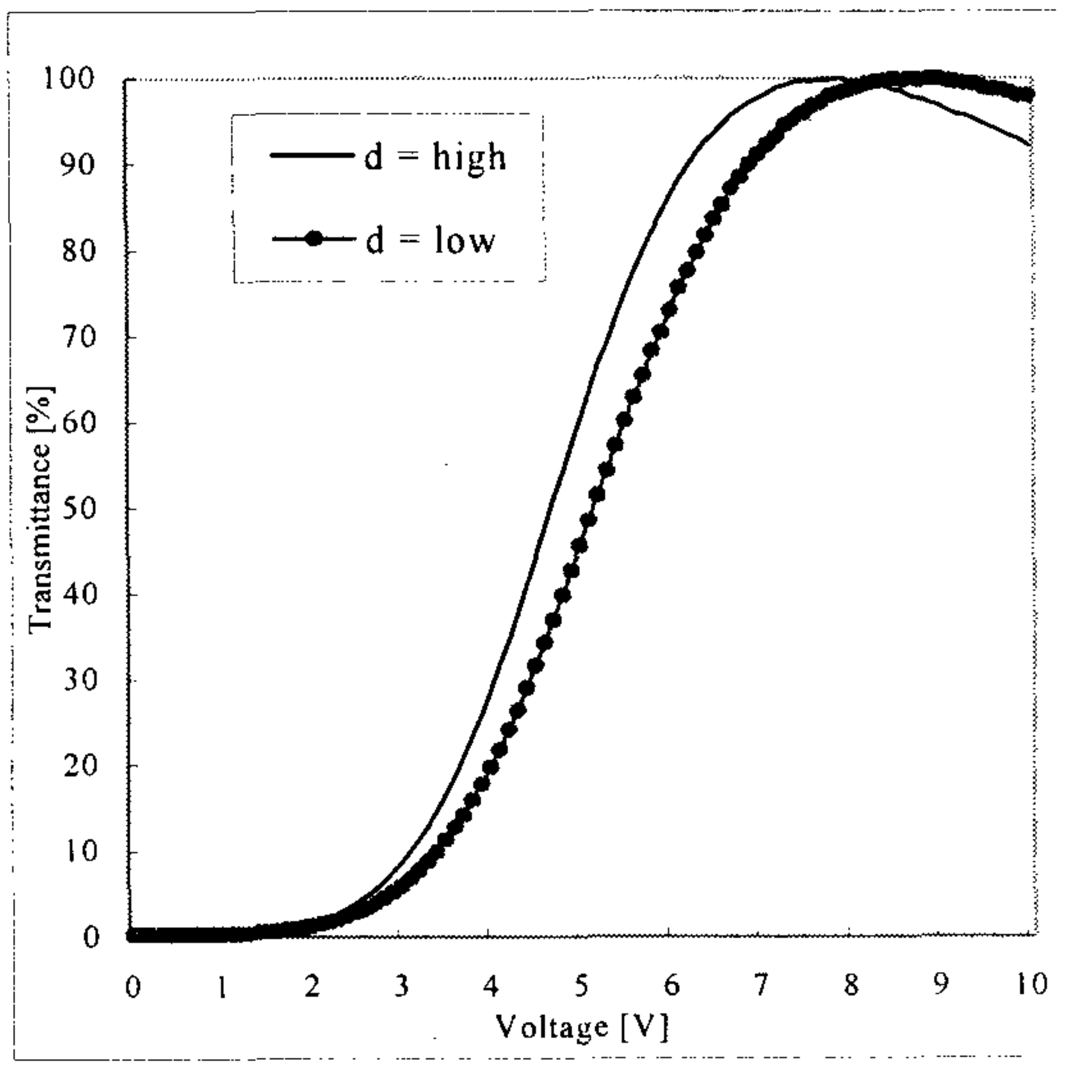


Figure 1. TV properties dependency on cell gap.

Therefore we need relatively high Δε LC mixtures without decreasing the viscosity . By using the newly developed liquid crystal mixtures containing -CF_2O-bridged phenyl compounds in Figure 2, we have obtained a sufficiently low operating voltage with a low cell gap that maintains a low viscosity and as result a fast response.

Development of fast response time LC mixtures for IPS mode

In IPS mode, the threshold voltage becomes higher upon reducing cell gap for fast switching or by widening the electrode distance for better aperture ratio. An increase of Vth should be compensated by increasing Δε. Thus, development of LC material was directed towards maximizing Δε at the same time as maintaining or lowering rotational viscosity (γ1) as much as possible.

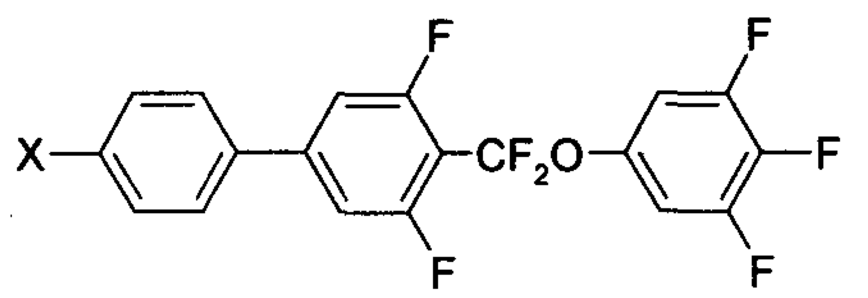


Figure 2 New LC single structure, (A)

Newly identified polar LC material class (A) is drawn in Figure 2 where CF2O group is linked between two fluorinated phenyl rings. In Figure 3, γ1 is plotted against Δε for the reference polar LC materials and new LC material (A). An increase of polarity is needed to reduce the voltage level but this, in turn, will increase rotational viscosity. The new LC materials, however, overcome this drawback, possessing a good combination of Δε (~25) and γ1 (~70-90 mPas).

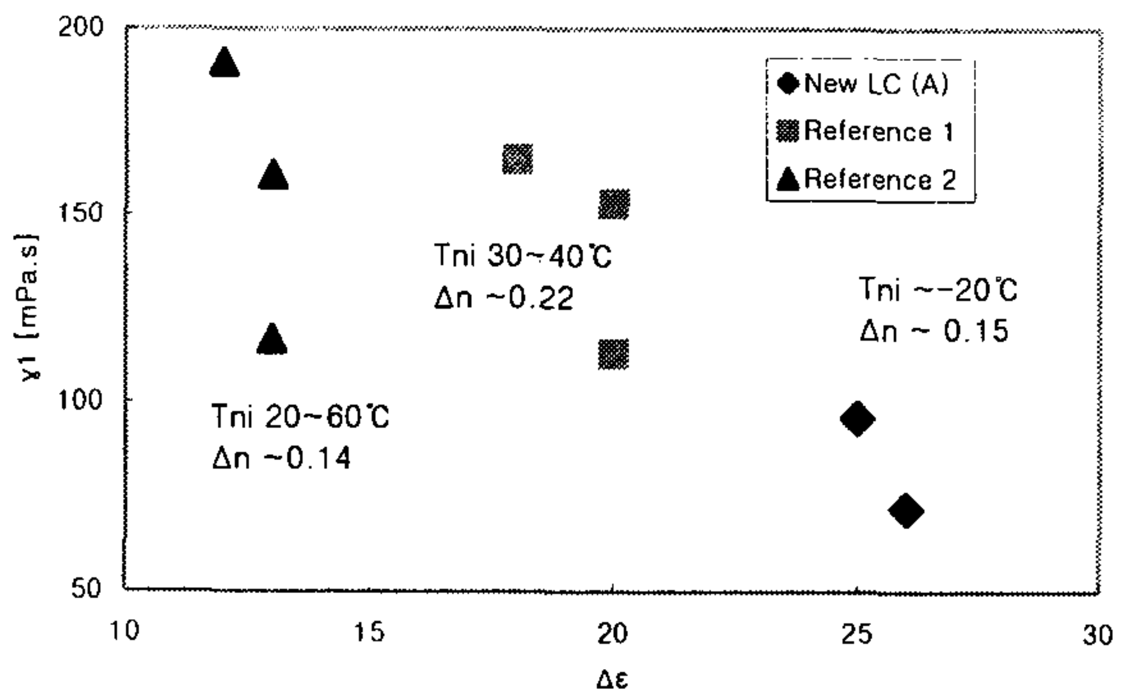


Figure 3 γ1 vs. Δε

Introduction of the new LC material (A) made it possible to develop the new mixtures with lower rotational viscosity in comparisons to reference mixtures as shown in Figure 4. A 16ms of response time was successfully achieved with these new mixtures which exhibit the γ1 value below ~80 mPas in the Δε range of 8-11. This is a significant reduction in γ1 in comparison to the reference mixtures for the response time of 30-35ms.

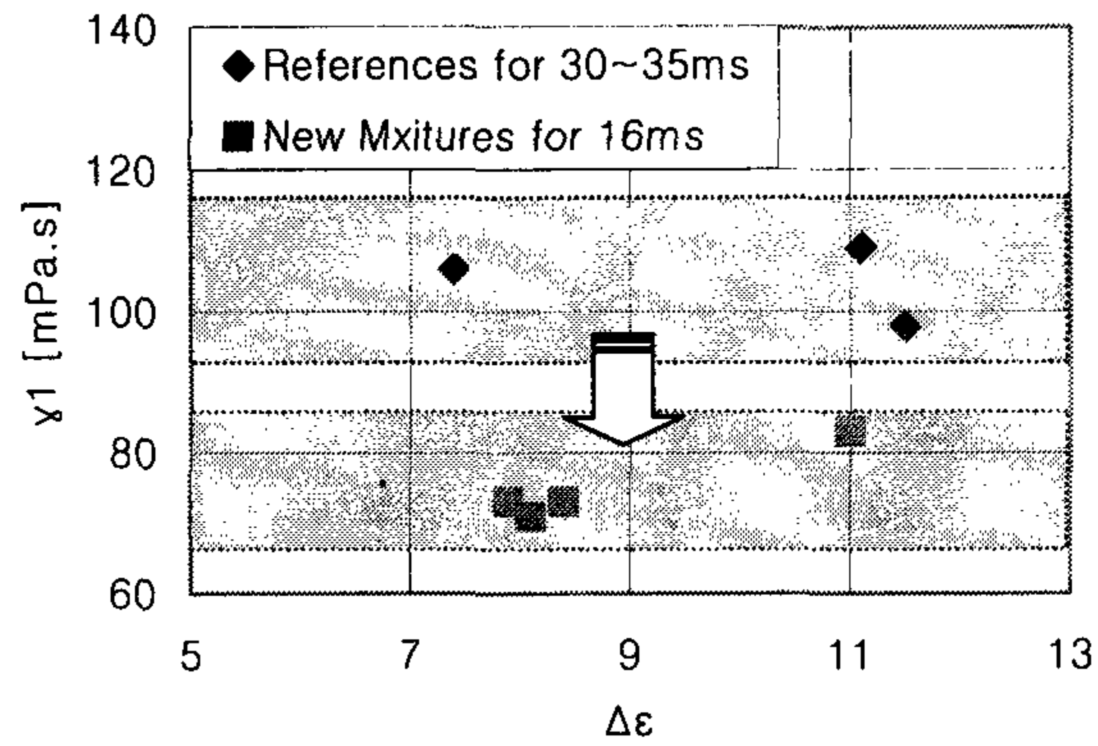
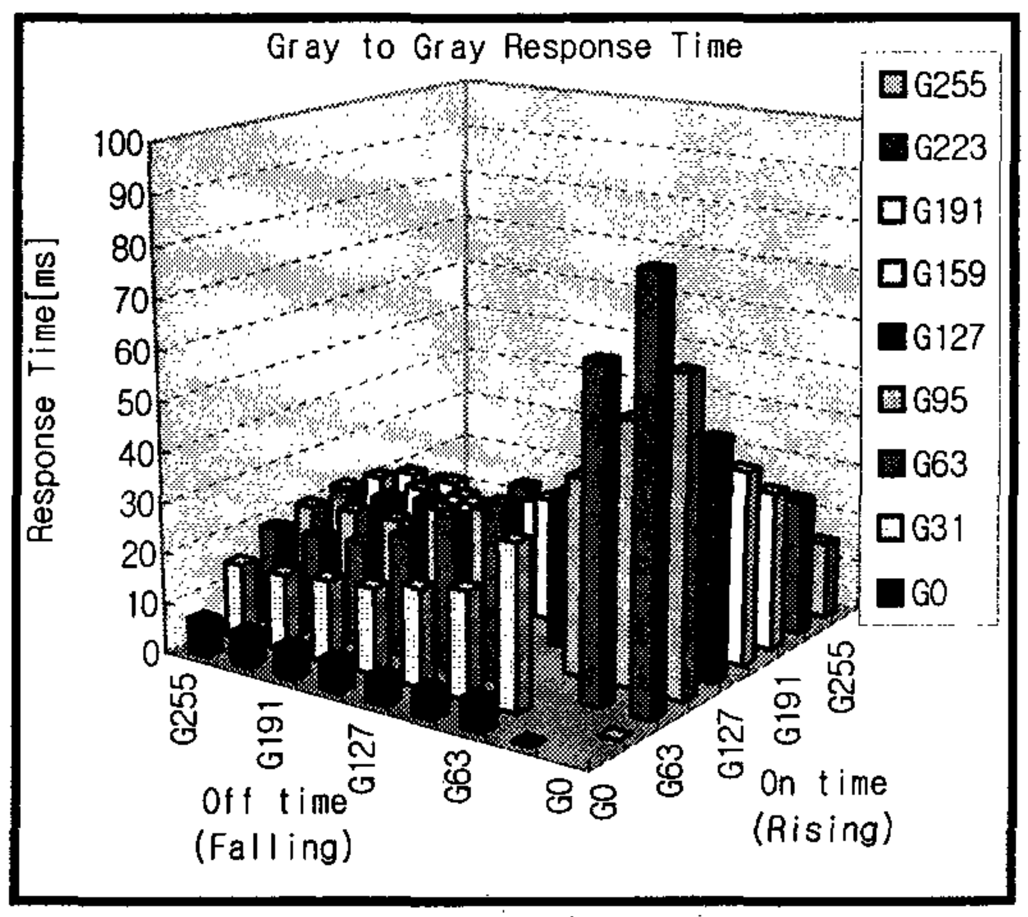


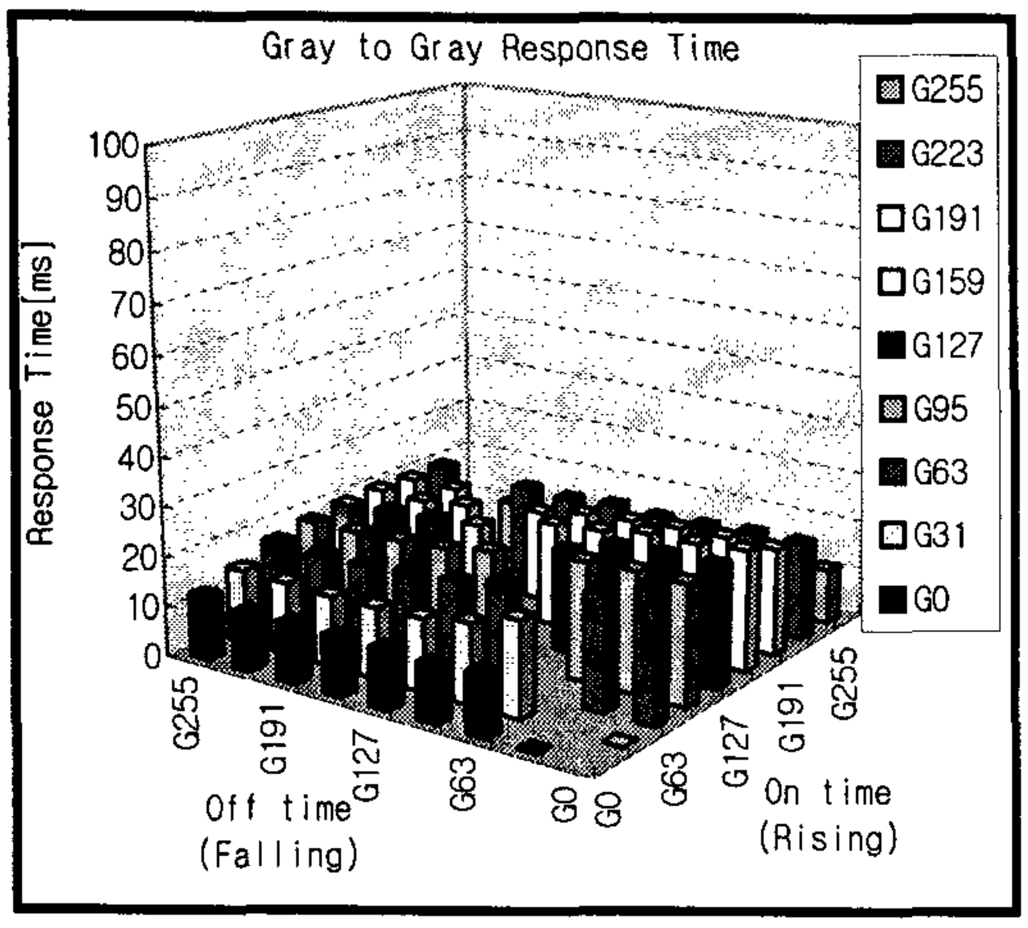
Figure 4 γ1 vs. Δε

Gray to gray response time

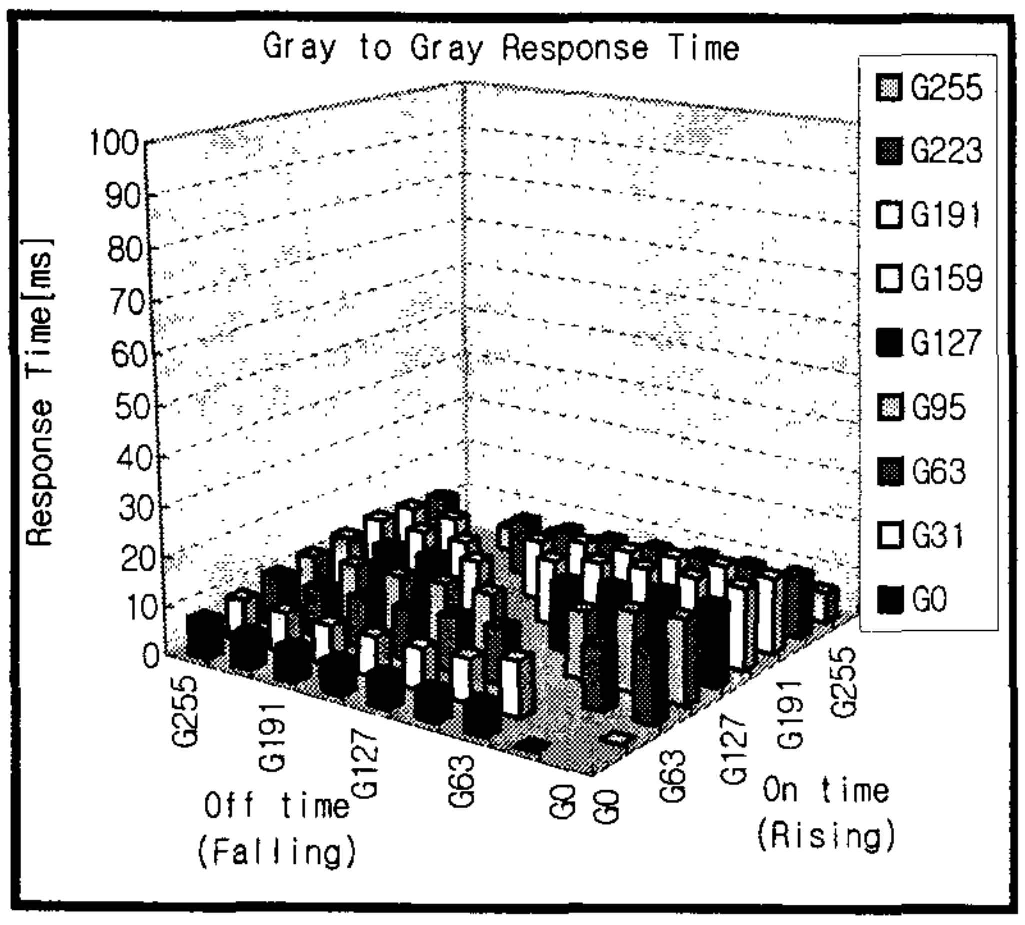
The lower cell gap contributes to fast response time. Figure 5 shows the situation of response time in VA-LCD, conventional IPS-LCD and newly developed IPS-LCD. The axis of x-y plane corresponds to the gray level for start and end, the vertical axis is response time. On the whole, the value of the τ max / τ min ratio of gray levels in the IPS modes is below 2.5.[4] This value is extremely small compared with that of the VA mode, which is above 50. This tendency is explained as a results of *Cst*/*Clc* ratio of intermediate gray levels.[5,6,7] The response time dependency in the case of gray levels is weaker in the IPS mode than in the VA mode.[1] The IPS mode also demonstrates a higher potential for displaying moving images.



[a]



[b]



[c]

Figure 5 Response characteristics between gray levels.

[a] VA-LCD (without ODC),

[b] IPS-LCD (conventional),

[c] IPS-LCD (newly developed model)

Considering tailing phenomenon which is caused by behavior of liquid crystal switching, we believe that IPS mode is a promising candidate to fulfill moving picture application. Moreover, many new technologies have been reported to improve motion pictures like scanning B/L. TFT-LCD is a hold-type device, and therefore is very effective to reduce motion blurring when a response time less than 16ms is achieved for all gray levels. [1]

Conclusion

By optimizing the cell configuration and the use of newly developed LC mixture, we succeeded in developing a 20.1inch UXGA TFT-LCD with the response time of 16msec. Super IPS mode makes it possible to get response time less than 16msec for all gray levels, which is necessary to reduce motion blurring.

Reference

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