The improvement of GTG response time using new concept LC mixture in S-IPS Mode for high frame frequency technologies

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Abstract

In order to satisfy with the clear visibility without any difficulties such as blurring and tailing, the high refreshing rate technology and fast response time of LC itself were applied to TFT-LCDs.

In proportion to the decrease of holding time of 1 frame, the fast transition of LC behavior was necessary to both maintain the luminance and minimize the tailing appearance. The introduction of a new LC mixture for faster response times was realized by the good combination of newly introduced dielectrically neutral LC material so called 'Super Low Viscosity' (SLV) and highly polar CF_2O-linkage LC material. This resulted in about a 20% reduction in the γ_1 of the new LC mixture compared to the references.

In accordance with a new LC mixture with low γ_1, fast response time of 5ms has been made for S-IPS LCD TV application.

Consequently, by applying the high frame frequency of 120Hz driving alongside the 5ms response time characteristics, the MPRT value was reduced by half.

1. Introduction

As digital broadcasting services have been started, more attention is being paid to the flat panel displays (FPDs), which offer the high definition (HD) pictures to the television viewers. Prior to the FIFA World Cup 2006, FPD TV sales are booming to enjoy more one of the major sporting events on the planet.

As the LCD manufacturing process improves, the prices will continuously drop and LCD market can be assured by a higher penetration rate of LCD TV into the CRT dominated TV market.

Since the advent of LCDs in the market, they have made a quantum leap forward in performance of brightness, viewing angle, color gamut, contrast ratio and response time. However, LCDs still have some technical issues remained to improve. In contrast to the impulsive types of displays such as CRT or PDP, LCDs exhibit what is described as 'holding picture problem' which can cause blurring of images and slower response time.

For the response time measurements, two kinds of response time definition can be applied to describe the difference between static and dynamic images. One is the conventional way related to the nematic liquid crystal mixture's response itself among gray to gray switching patterns to an external field, the other is new definition, so called moving picture response time (MPRT) related to the blurred image at the edge of a moving picture by the integrating human eye perception sense.

There are several ways to improve MPRT such as high frame frequency method or pseudo-impulsive method. Backlight technique or black data insertion method is used for the pseudo-impulsive method [1,2]. In this several method to improve MPRT, high frame frequency method is preferred as pseudo-impulsive method, because pseudo-impulsive method entails some disadvantage of decrease of luminance and contrast ratio. In order to maximize the efficiency of high frame frequency technology, development of rapid response technology is required. As shown in Figure 1, when frame frequency increases, the faster response time is required more. 16.7ms is required for one frame switching at 60Hz whereas 8.3ms at 120Hz.

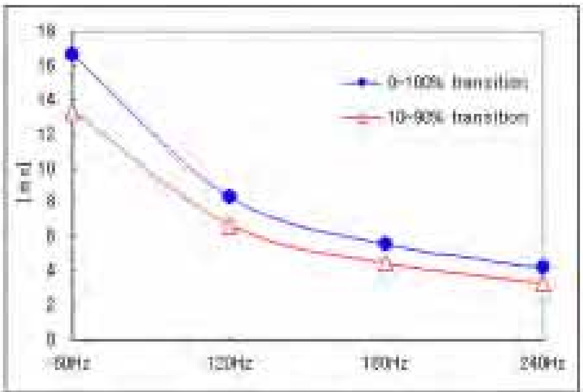


Figure 1. Required response time by driving frequency

However practically 16.7ms at 60Hz or 8.3ms at 120Hz are not faster enough for the one frame switching. Firstly, the standard measurement method suggested by VESA (Video Electronics Standards Association) take the time interval where brightness changes between 10% and 90% [3]. This means change in brightness should be done quicker for the correct marking of gray-to-gray response time. Therefore, response time between every gray should be within 13.3ms at 60Hz and 6.7ms at 120Hz. Secondly, maximum value of gray to gray response time is observed to be higher than the average value by 20% as for IPS mode. Therefore this should be also taken into consideration in order to mark necessary response time as average gray to gray response time.

Consequently, considering the two facts mentioned above, 10.7ms at 60Hz and 5.3ms at 120Hz are needed.

In this paper new LC mixtures with low rotational viscosity γ1 have been developed for the optimization of the response time at high frame frequency at 120Hz.

2. Theory

The rising and falling response time, t_r and t_f in IPS mode are expressed as in Equation 1 [4].
Where *l* is electrode distance, d is cell gap.

$$t_r \propto \frac{\gamma_1 \cdot l^2}{\varepsilon_0 \Delta\varepsilon (V^2 - V_{th}^2)}$$

$$t_f \propto \frac{\gamma_1 d^2}{K_{22} \pi^2}$$

Equation 1. t_r and t_f equation for IPS mode.

The rising time (t_r) can be reduced by increasing the driving voltage and reducing the γ1 of the LC mixtures. The falling time (t_f) is governed by the ratio of rotational viscosity and the elastic constant, γ1/ K_{22} [5.6].

3. Development

3.1 Low rotational viscosity (γ_1)

In IPS mode, the response time of LCDs is a relatively complicated function of driving method, cell configuration and properties of liquid crystal mixtures. Continuous efforts have been made to achieve the faster response time by lower cell gap, higher driving voltage and introduction of new LC singles (Figure 2). In the remarkable evolution of LCDs, the response time of 5ms gray to gray has been realized. Under development is to target faster response time of below 5ms.

Compare to the LC mixture used for 8ms gray to gray, γ1 of the newly developed LC mixture for 5ms gray to gray was reduced by 20% where combination of the 'super low viscosity' (SLV) and high polar CF2O-linkage LC material have been introduced.

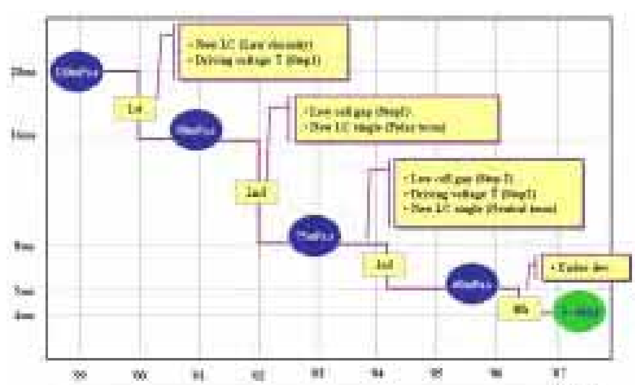


Figure 2. Response time improvement

3.2 High elastic constant (K_{22})

Falling time is more decisive factor to influence on the blurring phenomena. If the elastic constant becomes higher, faster response time can be obtained but increment of operation voltage will be followed. Therefore, LC mixtures are required to have an optimized $\gamma 1/K_{22}$ parameter to fulfill the response time target at the given cell structure design [7.8].

In Figure 3, $\gamma 1/K_{22}$ was plotted against the gray to gray response time target.

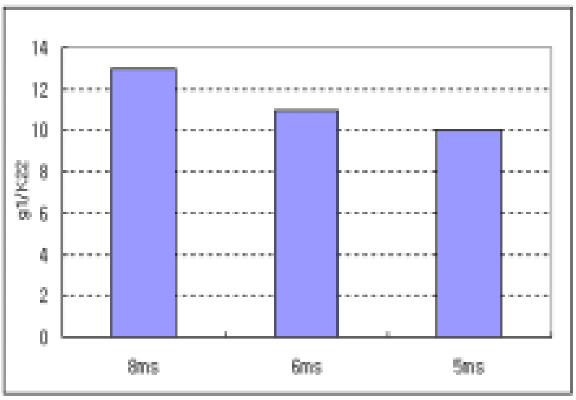


Figure 3. γ_1/K_{22} vs. response time

4. Experiment

4.1. The characteristics of LC mixtures for the reference mixture, MP and newly developed mixtures, Mix_1 and Mix_2 are summarized in Table 1. Compare to the MP, about 20% $\gamma 1$ reduction was achieved in the newly developed mixtures and additionally 5% increment of K_{22} in Mix_2 was made.

	MP	Mix_1	Mix_2
$\gamma 1$	73	61	59
(est.) K_{22}	5.8	5.7	6.1
$\gamma 1$ / (est.) K_{22}	13	11	10

Table 1. Physical properties of LC mixture for IPS

4.2. IPS experiment panel fabrication

42" IPS test panels were fabricated in the 6th generation line (glass substrate size 1500 × 1850), then to be equipped to the LCD module state.

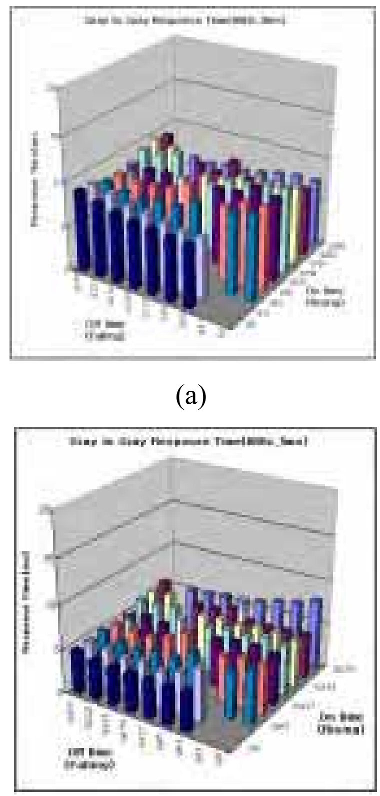
5. Measurement & Result

5.1. Response time measurement

Response times of IPS test LCD module were measured with Westar system (PR880).

5.2. Measurement results

Figure 4 shows 9X9 response time measurement results at 60Hz driving for LC mixtures, MP and Mix_2. Average 8.2ms, maximum 10.1ms were obtained with the LC mixture, MP whereas the newly developed Mix_2 exhibited average 5.4 ms, maximum 6.5ms response time.



(a) *Ave. 8.1ms Max.10.1ms*

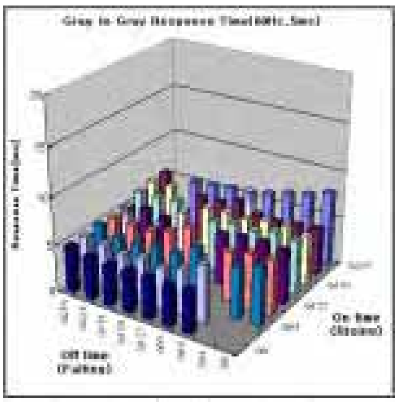
(b) *Ave. 5.4ms Max.6.5ms*

Figure 4. Response time characteristics between gray levels (a) conventional LC (MP) – 8ms (b) newly developed LC (Mix_2)-5ms

This response time result of new LC means 33% improvement in comparison with our conventional LC and this improvement is caused by $\gamma 1$ improvement for rising time and $\gamma 1/K_{22}$ ratio improvement for falling time.

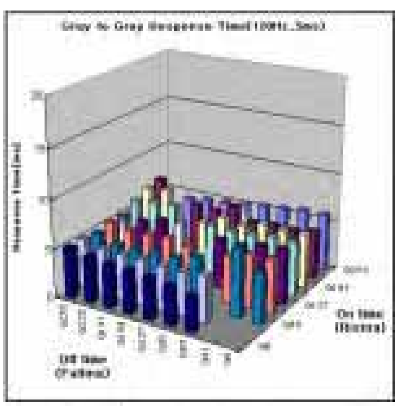
The max GTG response time result of the conventional LC is 10.1ms and there are some parts of data over 8.3ms that means one frame at 120Hz driving. This means that our old concept is inadequate to 120Hz driving because whole gray to gray response time should be satisfied with below 8.3ms at 120Hz driving. However the test LCD module with new LC has no problem at 120Hz driving because the test LCD module with new LC is satisfied with under 8.3ms, even less than 6.7ms that we previously mentioned, at the whole gray to gray area.

Figure 5 is 9X9 response time measurement result of the LCD module with new LC at 60Hz driving and 120Hz driving respectively. In this test, same test panel mentioned in Figure 4 has been used.



Ave. 5.4ms
Max.6.5ms

(a)



Ave. 5.2ms
Max.6.0ms

(b)

Figure 5. Response time characteristics between gray levels (a) newly developed LC 60Hz-5ms, (b) newly developed LC 120Hz-5ms.

In the 120Hz driving, we obtained a little faster result - avg. 5.2 ms and max 6.0 ms - than avg. 5.4 ms and max 6.5ms at 60Hz driving. Faster response time at 120Hz driving seems to be generated by “optimized fast refreshing effect”. This means that LC mixtures can react within the faster frame rate than 60Hz by regulating overdriving ratio.

6. Conclusion

By combining the new molecules called super low viscosity (SLV) materials with new sophisticated LC mixture concepts, we are able to achieve the faster gray to gray response time of 5ms, therefore significantly improving the previous 8ms gray to gray response time. This result, which takes advantage of low $\gamma 1$ as well as high K_{22} LC mixtures, is the basic background of the 120 Hz driving for reducing the motion blur phenomena. We expect that this outcome will be regarded as a cornerstone of the faster response time technique which is needed for the faster frame rate than 120 Hz.

7. Reference

[1] Sueoka, K., Nakamura., and Taira Y., SID ’97, 203(1997)

[2] Kurita T., SID ’01., 986(2001)

[3] VESA, Flat panel display merasurements standatd version 2.(2001)

[4] Jun-ichi HIRAKATA, Akira Shingai, Kikuo ONO, KAWABE and Tsutomu FURUHASHI

[5] M. Oh-e and K Kondo, Appl. Phys. Lett. 69, 623(1996)

[6] Shohei Naemura, IMID ’05 Digest, 36.1(2005)

[7] C. S. Lim, J. H. Lee, C. H. Oh, H. C. Choi, S. E. Lee, M. O. Jin, M. Klasen-Memmer, K. Tarumi : IMID ’03 Digest, 4.3(2003)

[8] C. S. Lim, J. H. Lee, H. C. Choi, C. H. Oh, S.D.. Yeo, S. E. Lee, M. O. Jin, D. J. Kang, M. Klasen-Memmer, K. Tarumi : IMID ’04 Digest, 26.4(2004)