15-4 : Development of an Advanced Double-Sided LCD Using a Single LC Panel and Two Lighting Systems for Mobile Applications

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Abstract

Using a single LC panel and two lighting systems, we have developed an advanced LCD system called "Double-Sided LCD." It has only one LC panel and two lighting systems, but it can display images of the same size and resolution on both the front and the rear side. Furthermore, utilizing a simple and thin lighting system we have reduced dramatically its module thickness up to 3.0mm, much thinner than that of conventional dual-type LCD, which is quite appropriate for the use of mobile applications.

1. Introduction

Currently, clamshell-type mobile handsets with dual-type LCD become very popular in many countries due to its own advantages like a convenience of using both sides' displays ; sub display for checking a simple information like time and date, main display for sending an email or taking a picture or browsing an internet. On the contrary, the clamshell-type handsets also have some inherent drawbacks such as increased thickness and a small display size in sub window compared to main display, making users reluctant to adopt them as the mainstream of display modules in mobile handsets. After the revolutionary hit of Motorola's RAZR in the worldwide, the general trend in mobile handset design has become how to make its thickness as slender as possible.

In order to meet these customer's requirements in dual-type LCD, last year we have developed a novel double-sided LCD with a single panel and one lighting system and reported our accomplishment to the proceeding of IDW/AD '05, which can display images of the same size and resolution on both the front and the rear side by using one LC panel and one lighting system [1-3]. However, in that case, even though our novel double-sided LCD has some distinguished features such as a very slim thickness, the total module thickness of 2.8mm and the simplest module structure, one LC panel and one lighting system, it has a critical disadvantage of inferior display quality in the sub side compared to that of main side, an indispensable consequence of adopting a frontlight unit as a lighting system[4].

In order to overcome this shortcoming of our previous version, we have upgraded both LC panel and lighting system as follows ; changing LC panel from transflective-type(TF) to transmissive-type(TM) and modifying the lighting system from frontlight unit to backlight unit respectively.

In this paper we will describe how to improve the display performance in our advanced Double-Sided LCD focusing on the advancement of display quality in the sub side and how to achieve such a slim thickness as thin as 3.0mm in spite of using two lighting systems.

2. Device Configuration

Fig. 1 is the schematic diagram to describe the overall structure of our advanced Double-Sided LCD. It consists of one transmissive-type(TM) LC panel and two backlight units (BLU-1, -2). Compared to our previous version of Double-Sided LCD using a single transflective-type LC panel and one frontlight unit, we have used transmissive-type LTPS-LCD of high performing characteristics like high resolution and high transmittance utilizing state of the art LTPS technology, and next generation lighting system with unique property of high transparent light-guide plate making the most of LED BLU technology in this advanced version of Double-Sided LCD.

Our dual lighting system consisting of two BLUs, where each BLU is composed of a single LED light source (2 chips in 1 package), light-guide plate and

outer mold frame, plays a crucial role in the operation of our Double-Sided LCD, working just like a conventional BLU system in the switch-on state as in the normal transmissive-type LCDs while functioning just like a transparent plate in the switch-off state as similar to FLU system in the reflective-type LCDs.

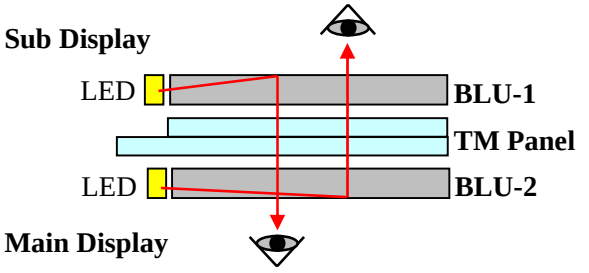

Fig. 1 Schematic representation of our advanced Double-Sided LCD in case of using internal lighting system

As mentioned in the former section, in order to satisfy the customers' requirement on reducing the module thickness as thin as possible, we have introduced an ultra-thin LC panel with a glass thickness of 0.3mm, so that the whole thickness of LC panel including two polarizers is as thin as about 1.0mm. We have also developed an ultra-slim and high brightness BLU system as thin as 0.8mm with the help of super-high luminescent LED chip (I_V=3,200mcd, I_F=20mA, 2 in 1 package). In addition to this effort of reducing the thickness of each component, we have also innovated the construction of our lighting system by eliminating all other optical sheets like prism, diffuser and reflector except for the light-guide plate in the BLU through the introduction of opto-electronic optimization technology between LC panel and lighting system.

As a result of our enthusiastic pursuit to lessen the total module thickness as thin as possible through adopting our creative way : one is to minimize the thickness of each essential component and the other is to simplify the construction of our lighting system as mentioned above, we could finally achieve the total thickness of as slender as 3.05mm in our advanced Double-Sided LCD, maybe the thinnest one ever made in the world.

3. Principle of Operation

As shown in Fig. 1, the main side is displayed only when the BLU-1 is switched on, located in the sub side, while the BLU-2 is kept off-state, playing a simple role of transparent plate, that is, just passing through the light without any loss of transmittance as little as possible. On the other hand, the sub side is displayed only when the BLU-2 is switched on, located in the main side, while the BLU-1 is kept off-state, playing the same role as explained in the case of main display. On both cases, since our advanced Double-Sided LCD is operated with a transmissive-type display, both sides' display shows a good optical performance with almost identical quality,

In addition, the ambient light can be used for the display of our advanced Double-Sided LCD, which is a great advantage in a viewpoint of power consumption for the mobile applications. As shown in Fig. 2, our advanced Double-Sided LCD is capable of using the ambient light for the display under bright sunlight conditions. In this case, since the light-guide systems in two BLUs are see-through, both the main and the sub side can be realized with a transmissive-type display without using any internal lighting systems. Due to this capability of using ambient light for the display, our advanced Double-Sided LCD can be a good potential candidate to replace the conventional dual-type LCD for mobile applications.

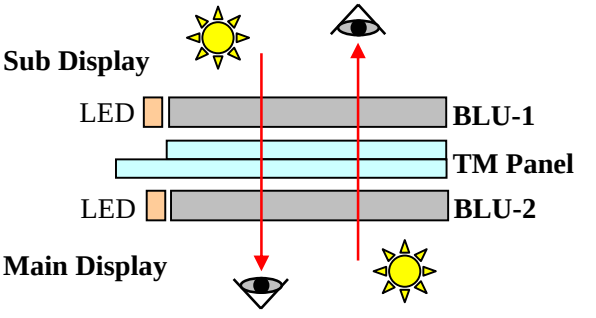

Fig. 2 Schematic diagram of our advanced Double-Sided LCD to depict the operational principle under ambient light

4. Display Performance

As the mobile handsets with built-in camera and DMB (Digital Multimedia Broadcasting) are gaining more and more popularity, so the end users request on the device quality is also growing higher and higher such that the top priority in the display quality is high

contrast ratio and good color reproducibility essential criteria for clear and natural image. And even for dual-type LCD customers need the display quality of both sides to be identical and excellent. This means that customers' requirement on the display quality is becoming more and more stringent. In response to this market's requirement, we have upgraded our previous version of Double-Sided LCD constructed with one transflective-type LC panel and one lighting system into this much advanced version through full-scale modification of our device configuration as mentioned above.

From this total reconstruction of our Double-Sided LCD, we're able get greatly improved display performance compared with that of our previous version, as listed in Table 1. The major advancement between old and new version is astonishing improvement in the display quality of the sub side : from 5:1 and 60 nits to 300:1 and 250 nits in contrast and brightness respectively, owing to introducing improved structure of optical design to make the most of transmissive-mode in the sub-side display in comparison to the use of reflective-mode in the old version. So that, we expect that there is no longer worry about the difference of display quality between main side and sub side in our new version since it shows almost equal optical performance between main and sub side.

Table 1 - A brief specification of our prototype advanced Double-Sided LCD

Item	Specification
Display Size	2.2" (diagonal)
Resolution	qVGA(240x320)
Brightness	Main : 250 nit(typ.) Sub : 250 nit(typ.)
Contrast Ratio	300 : 1 (M, S)
No of Colors	262K
No of LEDs	2 Chips (I = 20mA)
Color Gamut	NTSC 64%
Module Thickness	3.05t (w/o chassis)

And although taking an unfavorable structure in view of thickness-wise in this new version, we can manage to keep the total module thickness as thin as 3.0mm through the full-scale effort to minimize the thickness in comparison to 2.8mm in the old version. Table 1 shows a brief specification of our Double-Sided LCD, where M, S means Main and Sub side respectively.

We have also improved the color gamut from 50% to 64% NTSC, taking into account market's trend demanding for better color reproducibility wide enough to display natural and vivid color in the mobile handset devices. As the mobile information tools like PMP(Portable Multimedia Player), Cellular Phone are expanding their inherent territory into TV region with swiftness, end users' requirement on the display performance is also growing into a higher level as good as that of conventional monitor or TV.

Fig. 3 shows photographs of our advanced Double-Sided LCD. As can be easily discerned from a single sight, display performance between main side and sub side is almost indistinguishable, the same level of contrast, brightness and color gamut as each other. In comparison to our old version, display quality of the sub side in our new version was greatly enhanced, due to our innovative design modification in both LC panel and lighting system as mentioned above.

(a) Main Display (b) Sub Display

Fig. 3 Photographs of our 2.2" qVGA advanced Double-Sided LCD in prototype, where (a) is a main-side display and (b) is a sub-side display, showing almost identical display performance.

5. Conclusions

We have developed successfully 2.2" qVGA advanced Double-Sided LCD module with both good optical performance and ultra-slim thickness. It possesses the following distinguished features.

First, it has ultra-slim module thickness. Even though using one LC panel and two lighting system, we're able to reduce the total module thickness of our advanced Double-Sided LCD up to as thin as 3.0mm due to our innovative approach to lessen the module thickness as thin as possible.

Second, it shows the identical display performance between main and sub side. Compared with previously publicized Double-Sided LCDs[1-3], the display performance in the sub side in our advanced Double-Sided LCD is clear and excellent, almost as identical as that of the main side, a major distinctive advancement in our new device.

Third, regardless of ambient condition of luminance, dark or bright, it has good visibility on both display sides. Due to this advantage of using environmental lights, we can adjust brightness level of our lighting system according to the degree of illuminated light intensity in the circumstances, resulting in reduction of power consumption. From this capability of adjustment in the brightness level, we can drastically reduce the power consumption in our advanced Double-Sided LCD.

Fourth, it is inherently privacy protective. Compared with the previous version of Double-Sided LCD, to display the same image into both sides simultaneously, our new device has a good characteristic of privacy protection, to display image into only one side selectively through the selection of lighting system between two BLUs, essential for the convenience of mobile handset users.

From these distinctive characteristics we think that this novel display device has high potential power to dramatically change the applicability and design concept of mobile information tools. We believe that these devices will be able to be used in novel applications such as see-thru slide handset device or dual-folder multimedia device and their market will be expanded in the future hopefully to be ignited by an initiative to replace the current dual-type LCD.

6. Acknowledgements

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7. References

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