Abstract

It is complicated to generate overdrive look-up table because the overdrive values are dependent on several factors such as response time, gamma curve and optical overshooting recognition of LCD panel. To obtain the optimal overdrive levels, we experimented three 15.4-inch WXGA panels with different response time and gamma. Based on the experimental analysis, we present a simple method of producing overdrive look-up table automatically and the resulting correlation coefficient with the manually produced look-up table is higher than 99%.

1. Introduction

Overdrive technology has been developed in LCD panels to improve LC response time [1]. Slow response time of LC causes the motion blur artifacts. In these days, the demand for fast response time and motion blur reduction of LCD panel has been increased in Note PC applications and the overdrive technology is widely adopted to small size under 20-inch panel. In order to achieve target gray to gray response time, overdriving gray levels are adjusted manually for each gray to gray transition. Though optimal overdriving levels produce faster LC response time and motion blur reduction, overdosed overdriving levels can cause side effect which is seen as brightened or darkened double edge around moving edge [2]. Furthermore, the manual process takes several days to complete overdrive look-up table.

Several methods of obtaining overdrive level automatically were proposed [3-5]; however, those methods which are based on LC response curve do not present varying overdrive level over all gray to gray transition, and do not reflect human visual sensitivity [3-4]. Even in the case of method that considers human visual sensitivity [5], the response time of each gray to gray transition and the previous overdrive values of the other panel with same gamma should be known before obtaining the optimized overdrive values for the objective panel, otherwise, the overdrive value cannot be obtained. Because this method is not based on the LC characteristic, the obtained overdrive value may be overdosed, so this method cannot be guarantee to prevent double edge in moving edge.

In this paper, we propose a new method to automate the optimized overdrive look-up table for TN mode panels in Note PC applications. The proposed method is based on the experimental result of lightness difference to be perceived by human, and is compared with the result of the manual tuning process.

2. Overdrive Optimization Using Conventional Method

To find out the optimum overdrive gray level, three different 15.4-inch WXGA panels were employed in the experiment. They have difference in response time, gamma curve as shown in Table 1. Panel 1 and panel 2 have same gamma curve and different liquid crystal. Panel 2 and panel 3 have same liquid crystal and different gamma curve.

Table 1. Specifications of three 15.4-inch WXGA panels

<table>
<thead>
<tr>
<th></th>
<th>Panel 1</th>
<th>Panel 2</th>
<th>Panel 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Off Response Time</td>
<td>16 ms</td>
<td>8 ms</td>
<td>8 ms</td>
</tr>
<tr>
<td>Gamma</td>
<td>2.2</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Operation Voltage</td>
<td>4 V</td>
<td>4 V</td>
<td>4 V</td>
</tr>
</tbody>
</table>

To optimize overdrive level of these three panels, we utilize an overdriving adjustment system. This system is composed of a luminance measuring equipment of BM-7, oscilloscope and PC. The PC contains a program which makes it possible to change the overdrive level manually and show the gray to gray scroll pattern according to each overdrive level. The BM-7 captures the change of luminance from the screen and the oscilloscope transforms this change into response curve. For each time when overdrive level is changed and a test pattern is scrolled, the observers see whether the moving edge of the scroll pattern has brightened or darkened double edge or not as shown in Figure 1. The double edge problem appears when overdrive is overdosed, and is related to human visual sensitivity. Until edge blur is improved and double edge effect disappears, the above overdriving adjustment process is continued. Accordingly, we can obtain optimal overdrive level of look-up table and analyze the experimental result for each panel.

(a) Clear moving edge.
Figure 1. Scroll pattern of dark gray to bright gray. After the manual process of overdrive adjustment, the optimum overdrive look-up tables are created as shown in Figure 2.

Figure 2. Optimum overdrive look-up table created manually.

3. Overdrive Optimization Algorithm

It can be observed that the threshold luminance of overdrive is varying according to each gray-to-gray transition. Especially, the overdrive level of falling transition is about 10 times the overdrive level of rising transition as shown in Figure 3 because the double edge is more perceived at falling transition than rising transition. Undershooting luminance level at falling transition should be adjusted more elaborately under 1% luminance difference.

In the case of gamma base on method, the constant threshold luminance values were not obtained. This phenomenon is caused by the non-linearity of human visual sensitivity. The perceived lightness by human vision is more sensitive to luminance difference in the dark region than the bright region as shown in Figure 4. In addition, this relationship can be represented through the following equation which was quantified by CIE1976:

\[
L^* = 903.3 \cdot \left( \frac{Y}{Y_n} \right) \quad (Y/ Y_n) \leq 0.008856
\]

\[
L^* = 116 \cdot \left( \frac{Y}{Y_n} \right)^{1/3} - 16 \quad (Y/ Y_n) > 0.008856
\]

where \( L^* \) is perceived lightness, \( Y \) is relative luminance, and \( Y_n \) is reference white luminance. This lightness equation can be rewritten by combining with the equation, \( L=x^\gamma \), which means the normalized luminance, \( L \), is proportional to some power of the normalized signal amplitude, \( x \). The normalized luminance can be expressed as \( Y/Y_n \). The resulting equation is given as follows:

\[
L^* = 903.3 \cdot \left( \frac{x}{64} \right)^{2.2} \quad L \leq 0.008856
\]

\[
L^* = 116 \cdot \left( \frac{x}{64} \right)^{2.2/3} - 16 \quad L > 0.008856
\]

where \( x \) is gray scale of video signal. In this equation, gamma 2.2 and 64 gray levels are adopted.

The equation (2) is plotted in Figure 5. It is observed that perceived lightness is almost proportional to the input gray signal. To calculate the optimal overdrive level, we employed this linear relationship between the perceived lightness and input gray signal. By applying equation (2) into the values of overdrive look-up table, we can obtain the relationship a constant value relating to overdrive level.
In the moving pattern as shown in Figure 1(b), the gray transitions order is dark starting gray, overshoot gray, and bright ending gray at rising edge. Human visual system perceives the lightness difference of dark starting gray and overshoot gray at first, and then see the difference of overshoot gray and ending gray. The former gray transition perception takes an effect on the latter perception. Therefore, if the ratio of the lightness difference: the lightness difference of dark starting gray and overshoot gray, that of overshoot gray and ending gray, is less than 0.2±0.02, the overshoot gray is not perceived by human eyes. The constant 0.2 is obtained by substituting the calculated perceived lightness values of above manually created look-up table into equation (3).

Equation (3) can be applied to panels under 8 ms on-off response time and various gamma curves exactly, even though the panel has different gamma curve. The fact that there is correspondent lightness graph to changing gamma curve makes it possible. For the liquid crystal with slower response time, because the rotational viscosity is higher than fast liquid crystal, it is difficult to reach the target transmittance during overshooting time. Therefore, we create weighting value to overdrive panels with slow response time in terms of rotational viscosity, cell gap, and anisotropy of dielectric constant and average elastic constant of the LC material. As a result, equation (3) is changed into equation (4).

\[
\frac{|L^*(\text{overdrive gray}) - L^*(\text{stop gray})|}{|L^*(\text{overdrive gray}) - L^*(\text{start gray})|} = 0.2 \pm 0.02
\]

\[
0 < \alpha \leq 1
\]

The procedure for estimating the optimized overdrive look-up table is shown in Figure 6. If gamma curve and a calculated LC characteristic value of an arbitrary panel are given, gamma curve data are transformed to lightness values according to gray levels by equation (2). The gray to lightness values are saved in memory, and their values are used for finding overdrive gray for all gray to gray transition. As a processing result, the obtained gray levels are saved into the overdrive look-up table.

4. Verification
We compared the result of the manual overdrive generation with the automatically calculated overdrive generation in terms of motion picture response time (MPRT) which is measured by OTSUKA MPRT-1000. Figure 7 shows the MPRT results of panels with different overdrive method. The MPRT using the proposed method is slightly higher than that using the manual processing method because the overdrive of calculated look-up table was obtained by conservative calculation to prevent unique overshooting in images. The correlation coefficient is 99 %, so the proposed method is useful to optimize overdrive look-up table.

5. Conclusion
By the proposed method, the optimal overdrive values of look-up table can be obtained efficiently and accurately. The calculated value by the proposed method reflects human visual perception in moving pattern, LC characteristic, and gamma curve. This programmed method can save time into less than 5 min to create the look-up table for arbitrary LCD panels and does not need a lot of memory because the proposed method employs a simple gamma curve and one calculated LC characteristic value. Furthermore, the proposed method has superior performance to guarantee clear moving edge to the previous methods.
6. References


