# Comprehensive Analysis of MNT Low-Power Consumption

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## Abstract

In order to reduce the total power consumption of QHD monitors, we propose two novel pixel structure design, TPS and DTP, which can improve transmittance by 10-15% compared to conventional designs, and the product with these two pixel designs are also comparable to the mass production products in terms of contrast and color gamut. Product used TPS and DTP pixel structure design can meet the production requirements of 8.6G factory and has passed the reliability test. It has the capacity of mass production and has a high guiding significance for the low-power products of QHD monitors.

## Author Keywords:

MNT, high transmittance, low power consumption, low cost

## 1. Introduction

Thin film transistor liquid crystal display (TFT-LCD) technology is widely used in screen display equipment such as TV and monitor because of its mature preparation process and low cost. There are three main modes of liquid crystal display technology, including twisted nematic (TN), vertical alignment (VA) and in-plane switching (IPS). The IPS mode exhibits wide viewing angle characteristics because the liquid crystals (LCs) are rotated in a plane parallel to the glass substrates. Fringe-field switching (FFS) mode is a display mode developed from IPS mode. The biggest difference between FFS mode and IPS mode is that the pixel electrode and the common electrode are not in the same layer, which makes FFS mode have faster response speed and higher transmittance than IPS mode.

Nowadays, countries around the world are paying more and more attention to environmental protection, and the Chinese government has even pledged to take effective policies and measures to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. In order to achieve these goals, addressing various energy efficiency issues is a priority. For the display industry, how to reduce power consumption of equipment while providing high-quality display effects is a difficult problem that must be solved.

At present, the volume of monitor on the market is generally stable, of which the proportion of quarter high definition (QHD) series is increasing year by year, and it will become the mainstream resolution in the next few years. So it is necessary to research and development the low power consumption of monitor QHD series. In recent years, the research on the low power consumption of TFT-LCD has been deepening. Reducing the power consumption of the backlight is one of the effective ways to reduce the overall power consumption of the display. However, the reduced power consumption of the backlight would lead to a decrease in the brightness of the display. The increase of aperture ratio of pixel region can improve the transmittance of the backlight effectively. Therefore, the pixel structure needs to be redesigned.

In this paper, we propose two novel pixel structure designs for QHD monitors. Firstly, we optimized the station position of PS and placed them on the TFT area, which we called TPS design. And then, we continued to optimize the TFT design, and proposed the dual TFT pixel (DTP) design. These two new pixel structure designs can effectively improve the aperture ratio of the pixel region, to achieve high transmittance under low power backlight conditions.

## 2. Pixel Design

It is well knowing that the direct factor affecting the aperture ratio of pixel is the area of black matrix (BM), and the aperture ratio of pixel will be higher while the area of BM is smaller. Fig. 1 shows the schematic of TPS design. It mainly optimized the conventional (one gate one data, 1G1D) pixel design and placed the PS on the TFT area, so that the BM above the gate line could block the gate line and PS together, which reducing the BM area dedicated to shielding PS and improving the aperture ratio of pixel.

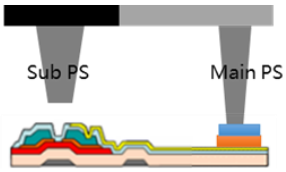


**Fig.1** TPS design cross-section.

In addition, we modify the TFT area based on TPS to further improve the pixel opening rate. The conventional 1G1D pixel design uses a U-shaped TFT in a sub-pixel, as shown in Fig. 2a. Compared with U-shaped TFT, L-shaped TFT has a smaller longitudinal width, which can reduce the width of gate line as well as the area of BM. Furthermore, by placing two TFT of two adjacent sub-pixels in a same sub-pixel, the BM area of the sub-pixel without TFT can be further reduced, as shown in Fig. 2b.


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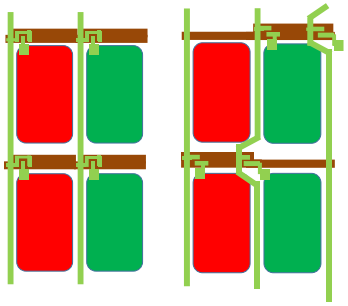
**Table 1** Optical Simulation Results of Different Pixel Specifications

| Items | L | S | Pitch | W | L/P | slit | LC optical efficiency |
|---|---|---|---|---|---|---|---|
| 1 | 2.2 | 4 | 6.2 | 12 | 35.48% | 10 | 26.57% |
| 2 | 2.5 | 4.3 | 6.8 | 12 | 36.76% | 9 | 26.46% |
| 3 | 2.8 | 4.8 | 7.6 | 12 | 36.84% | 8 | 25.18% |



(a) (b)

**Fig.2** (a) conventional 1G1D design; (b) DTP design.

Moreover, the conventional 1G1D design uses FFS display mode, as shown in Figure 3a, while DTP design uses IPS+FFS display mode, as shown in Figure 3b. Since T-ITO and M1 Com are different signals, there is no distance limit between them, and T-ITO can be used to cover the gate line in the pixel without TFT to shield the gate electric field.

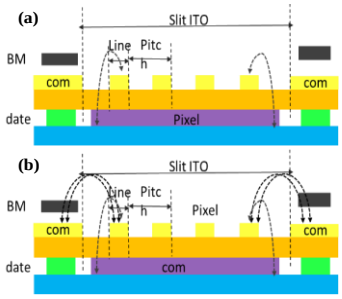



**Fig.3** (a) FFS display mode schematic; (b) IPS+FFS display mode schematic.

## 3. Result and discussion

### *3.1 Simulation*

At first, the pixel's characteristics is analyzed and optimized by using commercial simulator TechWiz LCD (Empyrean, China). As we know, the quantity and line width of slit as well as space between them are important parameters of top ITO. In order to obtain the best optical efficiency, we simulate the optical display of several sets of DTP pixels with different parameter specifications, and the results are shown in Table 1, where "L", "S", "W" represent line width of top ITO slit, space between slits, and slit distance between pixels respectively. It can be concluded from the simulation results that the best optical effect can be obtained when L/S=2.5/4.3 and the number of slit is 9, and the optical efficiency fluctuates little with the change of ITO CD, as shown in Fig. 4.

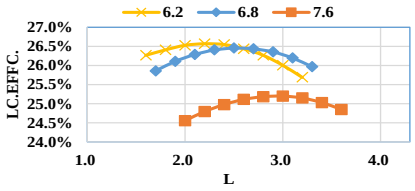
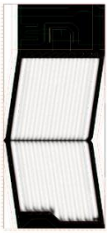



**Fig.4** Effect of ITO CD variation on optical efficiency of different pitch design

**Table 2** Transmittance Simulation Results of Different Pixel Designs

| Item | Ref | TPS | DTP |
|---|---|---|---|
| Figure |  |  |  |
| Tr | 5.6% | 6% | 6.33% |

Transmittance simulation results of novel pixel design and conventional pixel design were showed in table2. According to the results, the transmittance of conventional pixel design is 5.6%, while the transmittance of TPS design is 6%, an increase of 10%, and transmittance of DTP pixels is 6.33%, an increase of 15%. In addition, we had simulated light leakage in dark state of DTP pixel design, and the results were showed in table 3. The position of BM was simulated by shift in X direction and Y direction, and the results showed that there was no light leakage under the fluctuation of shift±4um in X/Y direction.

### *3.2 Analysis*

In order to further explore the performance of the two new pixel designs, TPS and DTP, we composed the panels of the two pixel designs into modules, carried out optical project testing, and compared them with the products already produced. The comparison results are shown in Table 4. It can be seen from the results that the transmittance and responding time of the products with TPS design or DTP design are both better than that of the mass-produced products, and the contrast ratio and color gamut are equal to that of the mass-produced products, which means that the overall optical performance of both TPS and DTP designs meets or exceeds the level of production products.

**Table 3** Simulation Results of Light Leakage in Dark State of DTP Pixel Design

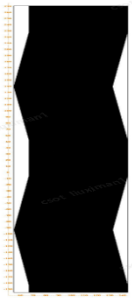
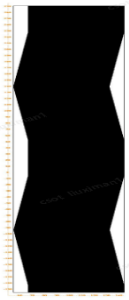
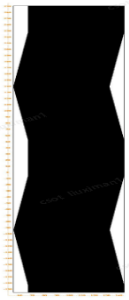
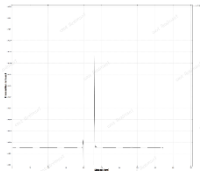
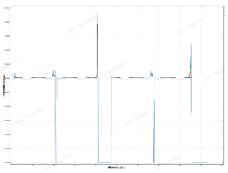
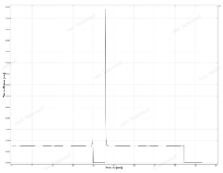
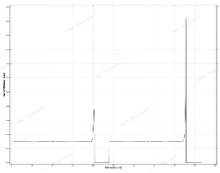
| Items | BM shift X-4.0um/Y-4.0um | BM shift X-4.0um/Y+4.0um | BM shift X+4.0um/Y-4.0um | BM shift X+4.0um/Y+4.0um |
|---|---|---|---|---|
| Result |  |  |  |  |
| |  |  |  |  |
| Peak value | 0.0021 | 0.00055 | 0.0028 | 0.0020 |

**Table 4** Optical Test Results for Different Products

| Items | Ref | TPS | DTP |
|---|---|---|---|
| Tr | 6.05% | 6.37% | 6.65% |
| CR | 1300 | 1334.5 | 1399.97 |
| Wx | 0.313±0.03 | 0.313 | 0.3102 |
| Wy | 0.329±0.03 | 0.324 | 0.324 |
| sRGB(CIE1931) | 99% | 99.95% | 99.9% |
| Response time （ms） | 14 | 11.25 | 11.315 |

We further explored the power consumption of different products, and the results are shown in Table 5. It can be seen from the results that while the products of TPS and DTP have excellent optical performance, the power consumption of the backlight used by them is lower than that of the mass-produced products, indicating that the products with TPS or DTP design can achieve the purpose of energy saving and emission reduction without reducing the display effect.

**Table 5** Power Consumption Test Results of Different Products

| Power Consumption | Ref | TPS | DTP |
|---|---|---|---|
| Open cell | 3.4W | 3.4W | 3.4W |
| Backlight | 8.22W | 7.36W | 6.95W |
| Total | 11.6W | 10.8W | 10.35W |

## 4. Conclusion

With the increasing market share of the QHD series in monitors, and countries pay more and more attention to the theme of energy conservation and emission reduction, the research and development of low-power QHD monitors is one of the market trends. We propose two new pixel designs, TPS and DTP. After optical simulation, we know that the optimal optical efficiency can be obtained when the L/S of Top-ITO is L/S=2.5/4.3 and the slit number is 9 for both pixel designs. In addition, the DTP pixel design performs well in dark-state light leakage simulation. The optical performance of the two pixel designs is further compared with that of the mass-produced products. And the results show that the performance of the two pixel designs is better than that of the mass-produced products in terms of transmittance and response time, and the contrast ratio and color gamut are also comparable to that of the mass-produced products. As for power consumption, the backlight power consumption of TPS and DTP design is lower than that of mass-produced products under the same open cell (OC) power consumption condition, which indicates that the use of TPS and DTP design can reduce power consumption while still providing high-quality display effect, achieving the purpose of energy saving and emission reduction, which is of great significance for achieving the goal of carbon neutrality.

## 5. Reference

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