# Solution for Horizontal Light and Dark Lines Issue of Z-zig Pixel Arrangement Liquid Crystal Display

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**ABSTRACT**

*Z-zig pixel arrangement is a common type in the field of Liquid crystal display (LCD), it has good anti-flicker performance and low power consumption. But, horizontal light and dark lines issue will appear because this pixel arrangement. There are two types horizontal light and dark lines, one is appear at gray level pattern, the other is appear at color mixed pattern..*

## 1 Introduction

Liquid crystal display (LCD) has been widely used for TV, monitor, notebook, pad and mobile phone due to its good optical performance and low cost. There are kinds of pixel arrangement in LCD, such as strip type, Z-zig type, dual gate type and tri-gate type.

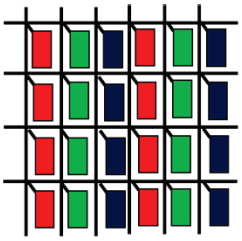

Fig. 1 Strip pixel

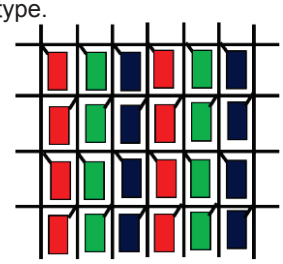

Fig. 2 Z-zig pixel

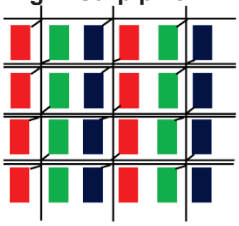

Fig. 3 Dual gate pixel

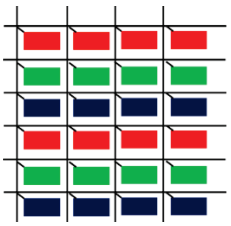

Fig. 4 Tri-gate pixel

At the same time, there are different kinds of data transmission, such as frame inversion, row inversion and dot inversion are used in LCD. The frame inversion type is with low frequency transmission, so it has the lowest power consumption, Fig.5.

The Z-zig pixel arrangement combine frame inversion can be realized dot inversion as a whole, Fig.6, which has anti-flicker performance and been lower power consumption, would keep balance between power consumption and display quality at the same time [1].

However, because of the parasitic capacitance with pixel and data line(Cpd), which cause Z-zig arrangement pixel has different brightness between line-N an Line N+1 at low gray level pattern, appear as horizontal light and dark lines. Also because of Z-zig arrangement, charging ratio of pixel N is lower than pixel N+1 at color mixed pattern(R/G,R/B.G/B), result in horizontal light and dark lines too. The detailed reason and root cause will be introduction later in this paper.

We will show experimental data, simulation data and improvement results in this paper, and found the key factor and design rule. Finally, these study proposed most suitable capacitor of Cpd, and best charging ratio to avoid the horizontal light and dark lines issue.

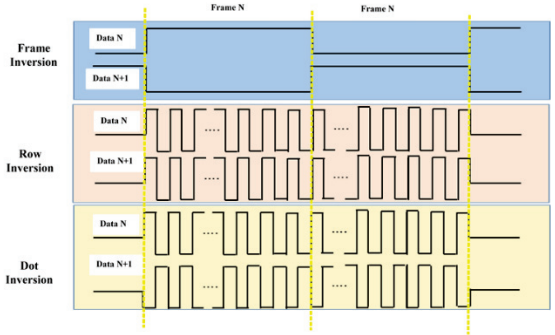


Fig.5 The data transmission inversion

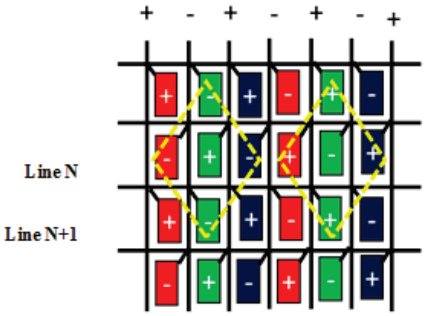


Fig.6 Z-zig pixel with Frame inversion

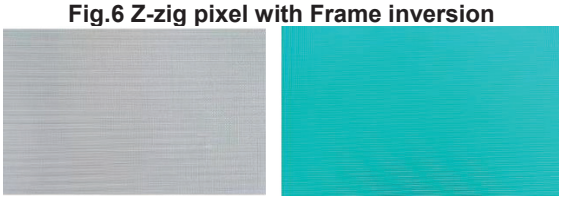

Fig.7 The phenomenon of horizontal light and dark lines at gray level pattern and color mixed pattern, G/B

## 2 Reasons of Horizontal Light and Dark Lines

### 2.1 At gray level pattern

Every pixel has two Cpd parasitic capacitance, pixel ITO with left data line and pixel ITO with right data line.

The capacitance value depends on the distance between pixel ITO and data line. Generally, the distance on the left and the distance on the right are equal, the capacitance value are also equal. So, the effects of parasitic capacitance on pixel will cancel each other [2].

But, in actual production process, because of process shift, the distance are not equal, the capacitance value are not equal. Pixel ITO shift right, for example, Fig.8

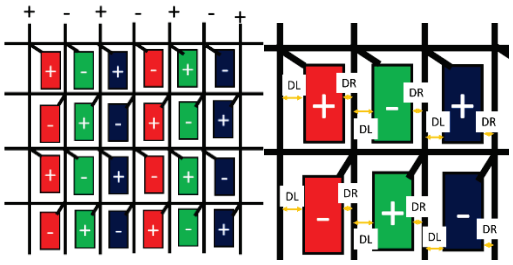


**Fig 8. Pixel ITO shift right, DL＞DR, CpdL＜CpdR**

When frame polarity inversion, data voltage changed. Positive polarity change to negative polarity, high voltage change to low voltage, generate negative coupling(↓) ; negative polarity change to positive polarity, low voltage change to high voltage, generate positive coupling(↑). The coupling of Cpd effect the pixel voltage, Cpd on the right （CpdR）has a greater impact. Pixels voltage will increase subject to positive coupling, and will decrease subject to negative coupling ,as shown in Fig9.

The voltage of positive-polarity pixel are higher due to positive coupling, pixels are lighter. The voltage of negative-polarity pixels are higher due to positive coupling, but pixels are darker. The voltage of positive-polarity pixels are lower due to negative coupling, pixels are darker. The voltage of negative-polarity pixel is lower due to negative coupling, but pixels are lighter, as shown in Fig 10. So, pixels in lineN are all lighter, pixels in lineN+1 are all darker, the horizontal light and dark lines are appear at gray level pattern. If pixel ITO shift left, pixels in lineN are all darker, pixels in lineN+1 are all lighter.

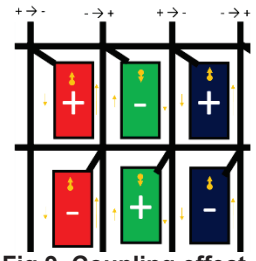

**Fig 9. Coupling effect**

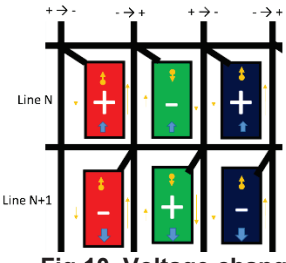


**Fig 10. Voltage change**

### 2.2 At color mixed pattern

The horizontal light and dark lines are also appear at color mixed pattern, R/G mixed pattern ,R/B mixed pattern and G/B mixed pattern. Take the G/B mixed pattern as an example in this paper. The G/B mixed pattern, G pixels and B pixels are light(L127), R pixels are dark(L0). The waveform of the data transition is different at one frame, D1/D3/D4/D6 have voltage change frequently, but D2/D4 are without change. Because of the voltage changed, the charging ratio of corresponding pixels are reduced, also cause lower pixel brightness.

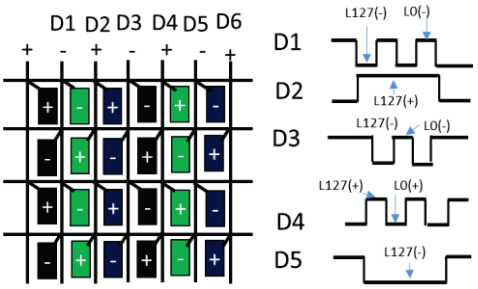


**Fig 11. G/B color mixed pattern and data transition**

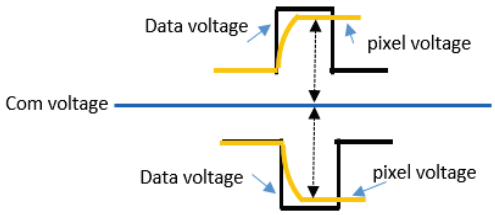


**Fig 12. Lower charging ratio with voltage change**

Due to lower charging ratio, pixels on D1/D3/D4/D6 have lower brightness, will looks darker. Pixels on D2/D4 have normal brightness. The darker pixel arrangement likes Z-zig microscopically, Fig.13, and appear horizontal light and dark lines macroscopically.

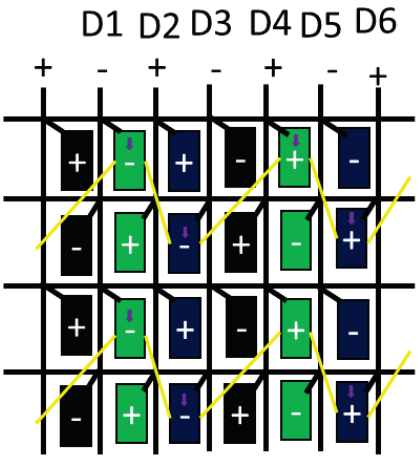


**Fig 13. Pixel brightness of G/B color mixed pattern**

## 3 Experiment for Horizontal Light and Dark Lines

In this experiment, HKC’s 31.5inch QHD（2560*1440）165Hz panel is taken as a test sample, this is a high resolution and high frequency panel, which has bad charging ratio. As mentioned before, Cpd is key factor for gray level horizontal light and dark Lines. We change the Cpd by distance modify and pixel ITO shift. The distance as shown in table1.

The color mixed horizontal light and dark Lines is cause by lower charging ratio as introduction before, we proposed method to improve charging ratio from three experiments:

1) Increase VGH voltage;

2) Enlarge the voltage gap between L0(+) and L0(-);

3) Over drive(OD)enhance;

About experiment 2), enlarge the voltage gap between L0(+) and L0(-) mean that the voltage gap between L0（+）and L127(+)is decrease, the voltage gap between L0（-）and L127(-)is decrease, as shown in Fig.14, a and b are decreased when c is enlarged, the pixels can charge more faster.

**Table 1. Different distance from ITO shift**

| Left/Right | Distance between pixel ITO and data line | | |
|---|---|---|---|
| ITO shift | 6um | 7um | 8um |
| 0um | 6um/6um | 7um/7um | 8um/8um |
| 0.5um | 5.5um/6.5um | 6.5um/7.5um | 7.5um/8.5um |
| 1.0um | 5um/7um | 6um/8um | 7um/9um |
| 1.5um | 4.5um/7.5um | 5.5um/8.5um | 6.5um/9.5um |
| 2.0um | 4um/8um | 5um/9um | 6um/10um |

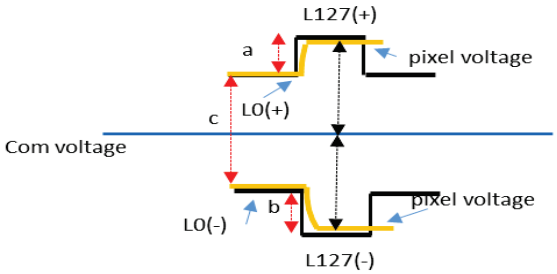


**Fig 14. Enlarge voltage gap between L0 (+) and L0 (-)**

## 4 Experiment Results and Simulations

In order to get the results of the experiment, horizontal light and dark lines phenomenon' level is divided to three classes, defined as "O", "△", "×". Level "O" means that the phenomenon is good. Level "Δ" means that the phenomenon is visible . Level "×" means that the phenomenon is bad.

### 4.1 Result at Gray Level Pattern

From this experiment result, the distance should keep more than 7um,and ITO shift less than 1.0um. The performance is acceptable for 31.5inch QHD165Hz panel.

**Table 2. Performance of gray level horizontal light and dark Lines with different distance**

| Performance | Distance between pixel ITO and data line | | |
|---|---|---|---|
| ITO shift | 6um | 7um | 8um |
| 0um | Δ | O | O |
| 0.5um | × | O | O |
| 1.0um | × | O | O |
| 1.5um | ×× | × | O |
| 2.0um | ××× | × | × |

### 4.2 Result at Color Mixed Pattern

From this experiment result, L0 voltage gap should keep more than 2.5V, and VGH voltage keep more than 30V.The performance is acceptable for 31.5inch QHD165Hz panel.

**Table 3. Performance of color mixed horizontal light and dark Lines with different voltage.**

| Performance | VGH Voltage | | |
|---|---|---|---|
| L0 voltage gap | 27V | 30V | 33V |
| 0.5V | ××× | ×× | ×× |
| 1.5V | ×× | ×× | ×× |
| 2.0V | ×× | Δ | O |
| 2.5V | × | O | O |
| 3.0V | Δ | O | O |

### 4.3 Cpd Simulation and Charging Ratio Simulation

The value of Cpd is simulation by capacitance extraction software, and we define a parameter A=Cpd/(Cst+Clc).Cpd effect pixel voltage, Cst and Clc can hold pixel voltage stably, So parameter A can used as a design rule. Simulation result is shown in table 4

The value of charging ratio is simulation by voltage extraction software. Simulation result is shown in table 5.

**Table 4. Cpd/(Cst+Clc) with different distance**

| Parameter A | Distance between pixel ITO and data line | | |
|---|---|---|---|
| ITO shift | 6um | 7um | 8um |
| 0um | 0.22% | 0.15% | 0.11% |
| 0.5um | 0.25% | 0.18% | 0.16% |
| 1.0um | 0.26% | 0.2% | 0.18% |
| 1.5um | 0.30% | 0.25% | 0.21% |
| 2.0um | 0.33% | 0.29% | 0.25% |

**Table 5. Charging ratio with different voltage**

| Charging ratio | VGH Voltage | | |
|---|---|---|---|
| L0 voltage gap | 27V | 30V | 33V |
| 0.5V | 88.6% | 89.8% | 90.0% |
| 1.5V | 90.1% | 90.7% | 92.3% |
| 2.0V | 91.4% | 93.8% | 94.7% |
| 2.5V | 93.0% | 95.0% | 95.5% |
| 3.0V | 93.8% | 96.7% | 97.2% |

## 5 Conclusion

Unblance of Cpd and unequal of charging ratio cause horizontal light and dark lines issue. Combining experimental and simulation results, we found the most suitable capacitor of Cpd, and the best charging ratio of the pixels to avoid the horizontal light and dark lines issue. The Cpd/(Cst+Clc) is less than 0.2% , and pixel charging ratio is more than 95%, the horizontal light and dark lines issue is disappear, which maintaining the LCD panel high performance.

## References

[1] Kun-Tsai Huang, the Correlation Analysis of Flicker Shift Phenomenon and Ion Accumulation Mechanism in FFS Mode LCD Panel, IDW 2016, pp. 123-126.

[2] Zeyao Li, "Analysis of Vertical Moiré-like Phenomenon of a Half-Source-Driving Liquid Crystal Display" Proc. IDW '18, pp. 200-203 (2018).