

# Word Crosstalk: Analysis of Causes and Assessment Criteria

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## Abstract

It is inevitable that signal crossover will result in horizontal crosstalk when scanning due to the parasitic capacitance inherent to TFT LCDs. Regular character patterns result in conspicuous crosstalk, affecting user experience. This paper name the special crosstalk 'word crosstalk,' and analyze its underlying causes, and severity assessment criteria.

## Author Keywords

Word Crosstalk; Horizontal Crosstalk; HCT; Text crosstalk; COM ripple; TFT LCD; Parasitic capacitance

## 1. Word Crosstalk Phenomenon

The word crosstalk phenomenon primarily manifests in three distinct forms including Text crosstalk, Excel crosstalk and PowerPoint pattern filling crosstalk.

1. Text crosstalk: In a text document formatted with Songti font size 12 ('small four' in Chinese typographic terms), , noticeable crosstalk is observed in lines without text boxes, with the capital letter 'W' being the most conspicuous (as shown in Fig.1.1).

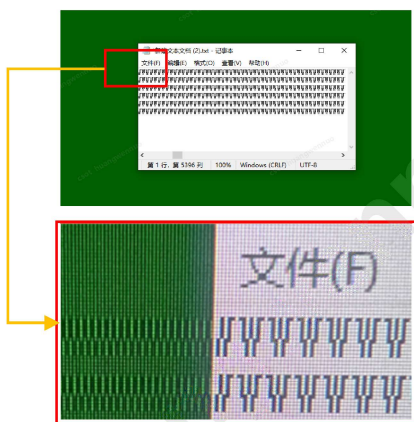


Figure 1.1. TXT crosstalk phenomenon

2. Excel crosstalk: In Excel, when the border is set to a dashed line, a distinct crosstalk phenomenon can be observed in the rows corresponding to the Excel frames as shown in Fig.1.2.

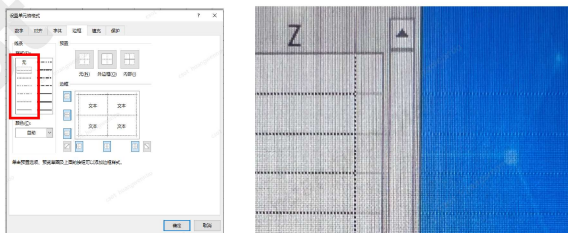


Figure 1.2. Excel crosstalk phenomenon

3. PowerPoint Pattern filling Crosstalk: In PowerPoint, when inserting shapes with pattern filling, certain fill patterns may induce crosstalk effects as shown in Fig.1.3.

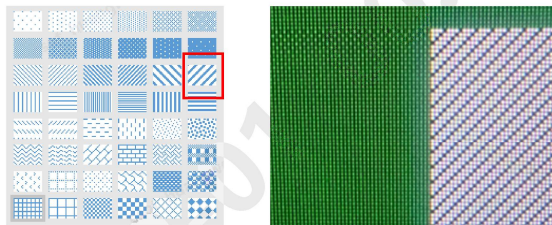


Figure 1.3 PowerPoint crosstalk phenomenon

## 2. Mechanism of Word Crosstalk

As demonstrated in the chapter 1, all crosstalk appears horizontally within the patterns, suggesting that word crosstalk is a type of horizontal crosstalk. To analyze the mechanism of word crosstalk, it is imperative to first discuss the mechanism underlying horizontal crosstalk."

### 2.1. Mechanism of horizontal crosstalk

The main four causes of horizontal crosstalk are listed below.

- i. Imbalanced positive and negative data signals couple to the COM voltage through parasitic capacitance, creating ripples. During charging, the data signal references an erroneous COM voltage, leading to the formation of H-crosstalk;
- ii. Line impedance causes variations in the in-plane COM voltage, with voltage being lower away from the fanout, resulting in horizontal display discrepancies;
- iii. Due to Gate RC Delay, the TFTs in areas distant from the gate fanout do not receive sufficient activation time, leading to horizontal display differences;
- iv. Sudden increases in load can overwhelm the driver's capacity, causing insufficient pixel charging and discharging, which results in crosstalk.

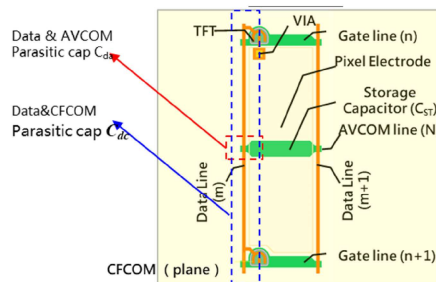


Figure 2.1. Pixel layout

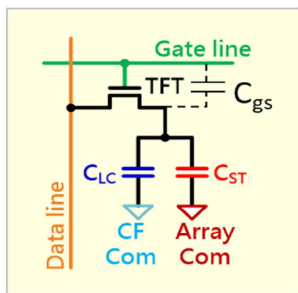


Figure 2.2. Equivalent circuit of pixel

Upon analyzing the text crosstalk patterns presented earlier, it is observed that crosstalk occurs when there is a change in pattern data. Therefore, it can be deduced that text crosstalk is primarily caused by the first of the aforementioned reasons, namely, the ripples in the COM voltage ( $V_{com}$ ).

Variations in the data signal couple through the parasitic capacitances  $C_{dc}$  and  $C_{da}$  to  $V_{com}$  referring to Fig2.1 and Fig2.2, thereby inducing  $V_{com}$  ripple. Consequently, the variations of  $V_{com}$  lead to the brightness and darkness display of pixel.

2.2. Mechanism of Text Crosstalk

The following analysis of the textual crosstalk phenomenon will focus on the panel with 1G1D FLIP architecture, using the letter 'W' as a case study. The figure of upon magnified letter 'W' is shown in Fig.2.3.

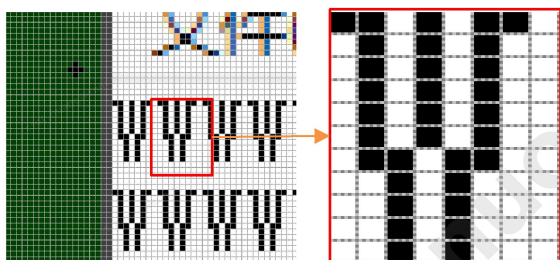


Figure 2.3. Magnified pixel image of the letter 'W'

According to the pixel arrangement of 1G1D FLIP architecture (as shown as Fig.2.4), the pixel distribution of the 'W' pattern is illustrated in Fig 2.5. As previously discussed, the  $V_{com}$  ripple is primarily induced by changes in the data signal. Consequently, these fluctuations in the data signal data signal of 'W' will lead to the change in  $V_{com}$ , thus bringing about crosstalk.

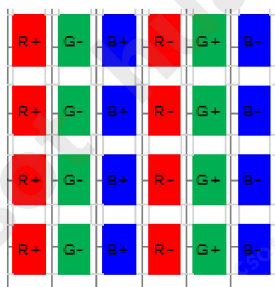


Figure 2.4. Pixel arrangement of 1G1D FLIP architecture

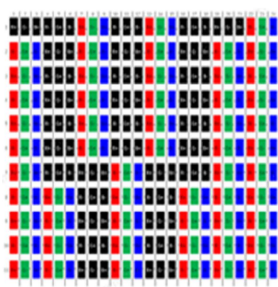


Figure 2.5. Pixel image of the letter 'W' in 1G1D FLIP

3. Criteria for Word Crosstalk Assessment

With the increasing prevalence of high refresh rate displays, it is necessary to establish uniform evaluation criteria for assessing panel performance with regard to word crosstalk. Three patterns (as shown in Fig. 3.1) have been designed based on the word crosstalk phenomena and mechanisms. They are designed to respectively characterize the crosstalk of the letter 'W', Excel, and PowerPoint.

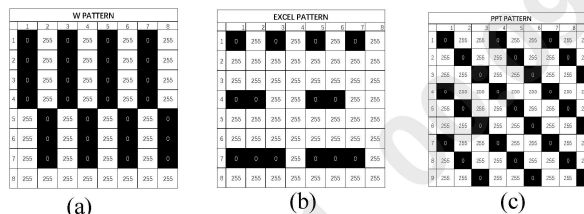


Figure 3.1. Pattern designed to (a) 'W', (b) Excel, (c) PowerPoint

3.1. Word Crosstalk JND

The number of crosstalk patterns directly influences the severity of crosstalk. In this experiment, the JND parameter is introduced to quantify this severity. During this experiment, the number of crosstalk patterns are gradually reduced to observe the maximum width at which crosstalk becomes undetectable. The wider the maximum undetectable crosstalk width, the more severe the word crosstalk. For this test, patterns representing 'W' text crosstalk, Excel crosstalk, and PowerPoint crosstalk (as shown in Fig3.3) are cycled across the entire row, with each pattern separated by a green background of shade 64 (as shown in Fig3.2).

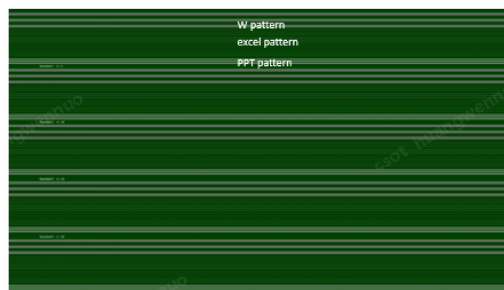


Figure 3.2. Test pattern for JND

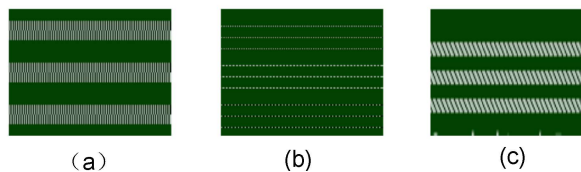


Figure 3.3. Magnified Test pattern (a) 'W' (b) Excel (c) PowerPoint

The crosstalk patterns are sequentially covered from left to right (Fig.3.4 (a)) and from right to left (Fig.3.4 (b)) using a 64 green mask. Fig.3.4 illustrates the width and position of 64 green mask. The visibility of crosstalk in the resulting 2x9 patterns is then assessed. Each pattern is evaluated as either visible (assigned a value of 1) or not visible (assigned a value of 0).

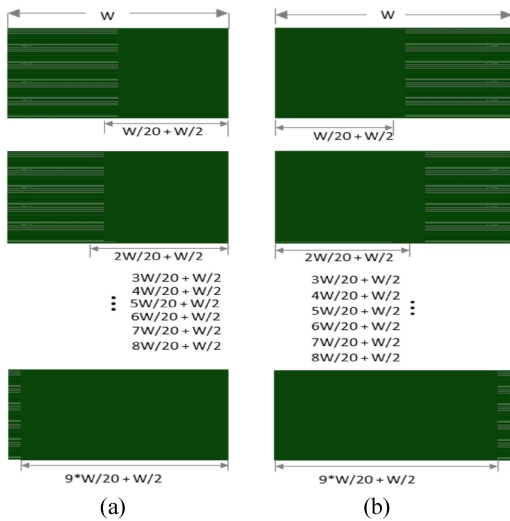


Figure 3.4. The width and position of 64 green mask (a) from right (b) from left

Filling in the determination results in the Table.1 as shown below.

**Table 1. JND point table**

Word CT JND									
	1	2	3	4	5	6	7	8	9
right									
left									
point									

The JND is determined by the minimum undetectable coverage amount. For instance, if covering 11/20 of the 'W' pattern results in undetectable crosstalk, the JND is assigned as 10 (Table.2: Example 1). Conversely, if the crosstalk remains visible even after covering 19/20, the JND is assigned as 1 (Table.2: Example 2). The detection results are assessed for each pattern, from Pattern 1 to Pattern 9. Starting from Pattern 9, the number of consecutive zeros is counted, and this count plus one is used as the JND for the minimum undetectable determination item (see Table.2: Examples 3 and 4). The following are several examples:

Table 2. Word CT JND Example

Example 1:									
Word CT JND									
	1	2	3	4	5	6	7	8	9
right	0	0	0	0	0	0	0	0	0
left	0	0	0	0	0	0	0	0	0
point									10

Example 2:									
Word CT JND									
	1	2	3	4	5	6	7	8	9
right	1	1	1	1	1	1	1	1	1
left	1	1	1	1	1	1	1	1	1
point									1

Example 3:									
Word CT JND									
	1	2	3	4	5	6	7	8	9
right	1	1	1	1	1	1	1	0	0
left	1	1	1	1	1	1	0	0	0
point									3

Example 4:									
Word CT JND									
	1	2	3	4	5	6	7	8	9
right	1	0	1	0	1	0	1	0	0

left	1	0	1	0	1	0	0	0	0
point	3								

### 3.2. The worst pattern judgment for Word crosstalk

The object of this experiment is to assess the severity of crosstalk under the most severe word crosstalk pattern conditions. To accurately determine the level of crosstalk severity, a judgment pattern (as shown in Fig.3.5) is created with a gray RGB (64,64,64) background. A crosstalk pattern with a width of 1/8 of the 'W' is inserted in this pattern. Additionally, based on the characteristics of gray-background textual crosstalk, a pattern of horizontally interwoven green and purple short lines is designed and inserted into the non-crosstalk areas of the test pattern as a standard reference (as shown in Fig.3.6). The standard is divided into four levels referring to Table.3, indicating increasing degrees of crosstalk severity. Table.3 lists the color coordinates of 4 standard and Fig.3.7 illustrates their location in CIE Chromaticity diagram.

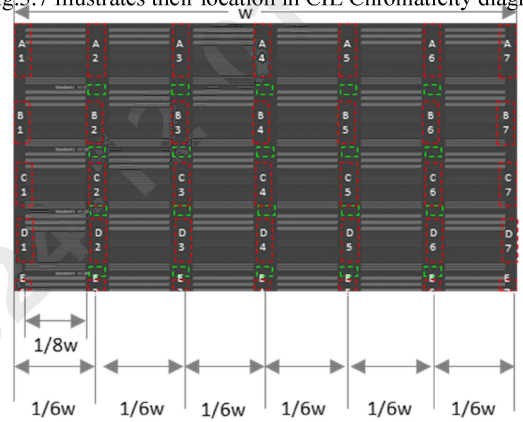


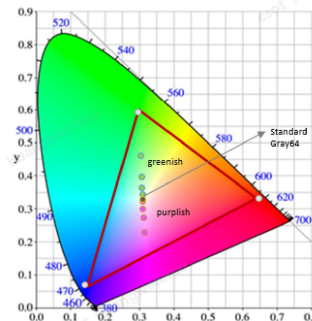
Figure 3.5. The worst pattern judgment



Figure 3.6. Standard 4 pattern

Table 3. 4 levels of standard and corresponding color

	R	G	B	color	x	y	Lum	AE2000
64Gray	64	64	64		0.313	0.329	5.127	0
Standard1	62	66	62		0.312	0.342	5.268	3.92
	66	62	66		0.3135	0.320	5.268	3.95
Standard2	59	69	59		0.311	0.363	5.502	8.62
	69	59	69		0.314	0.298	4.823	8.67
Standard3	54	74	54		0.31	0.397	5.948	14.31
	74	54	74		0.316	0.269	4.589	14.42
Standard4	44	84	44		0.306	0.464	7.058	20.94
	84	44	84		0.318	0.223	4.327	20.97



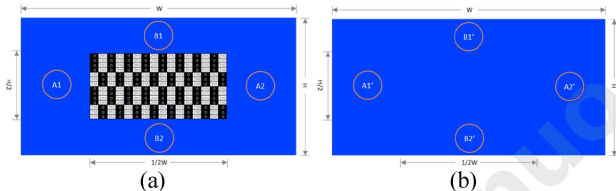
**Figure 3.7.** The colors of 4 Standard in CIE Chromaticity diagram Referring to Fig.3.5, observe all type of crosstalk phenomena (W crosstalk, Excel crosstalk and PowerPoint crosstalk) within the red dashed frame areas separately. Compare the most severe parts of these three types of crosstalk with the horizontal lines in the green frame standard area. Then, record the results in the Table.4. The specific evaluation criteria are also provided in the Table.4. If the crosstalk is more severe than Standard 4, assign a score of 0. If it is milder than Standard 1, assign a score of 5. Calculate the average value and the minimum value of the 35 points. The sum of these two values represents the score of this worst pattern judgment. For example, using the values filled in the Table.4, the final worst Pattern points are 3.6.

**Table 4.** the worst pattern judgment table

TXT CT worst pattern judge										STANDARD	
	1	2	3	4	5	6	7			<standard	5
A	3	3	3	3	3	3	3	3	3	standard1	4
B	2	2	2	2	2	2	2	2	2	standard2	3
C	1	1	1	1	1	1	1	1	1	standard3	2
D	3	3	3	3	3	3	3	3	3	standard4	1
E	4	4	4	4	4	4	4	4	4	>standard	0
avg.	2.6		min		1		point		3.6		

**3.3. Color Deviation of mix-color background**

The object of this experiment is to assess and quantify the impact of word crosstalk on color-mixed figure. The test background is a color-mixed blue screen with RGB values of (0, 64, 224), and the central pattern consists of the ‘W’ crosstalk pattern as shown in Fig.3.8.



**Figure 3.7.** Color Deviation assessment pattern

Measure and record the color points at four positions (as shown in Figure.3.7) with(a) and without(b) the crosstalk frame, and document them in the Table.5. Calculate the difference in color points at the same positions between the two images, and take the maximum value as the color deviation. If the maximum value is less than 1‰, the score is 10. If the maximum value is greater than 5‰, the score is 0.

**Table 5.** Color Deviation pattern assessment table

Mix color TXT CT COLOR DEV.							
	x	y	x	y	$\Delta x$	$\Delta y$	
A1	0.156	0.097	A1'	0.156	0.098	0.001%	-0.017%
B1	0.156	0.095	B1'	0.156	0.095	0.003%	-0.001%
A2	0.156	0.098	A2'	0.156	0.098	0.007%	0.010%
B2	0.156	0.097	B2'	0.156	0.097	-0.004%	-0.003%
standard			Max.		point		
MAX <1‰	10.000						
MAX <3‰	5.000						
MAX <5‰	1.000		0.000		10		
MAX >=5‰	0.000						

**3.4. Summary of Word Crosstalk Assessment Criteria**

This paper categorizes the evaluation of textual crosstalk into three sub-items:

1. Minimum Undetectable Textual Crosstalk Determination;
2. TXT CT Worst Pattern Judge;
3. Mix Color TXT CT Color Deviation.

These sub-items comprehensively assess the severity of textual crosstalk in the test sample from three aspects: the probability of user detection, the perceived severity, and the impact on the charging of mixed-color images. Considering the significance of influencing factors, a weighted score is assigned to each item. The total score for textual crosstalk evaluation is obtained by summing the weighted scores of each sub-item. A perfect score of 10 indicates that the test sample is free of textual crosstalk.

**Table 6.** Word CT assessment table

Word CT Assessment			
No.	Item	points	weight
1	Word CT JND		40%
2	TXT CT worst pattern judge		40%
3	Mix color TXT CT COLOR DEV		20%
Total.			

**4. Example of word crosstalk determination**

The evaluation results of text crosstalk for the three Monitor products are presented in Table.7, The LG ULTRAGEAR was found to exhibit the best performance in this regard.

**Table 7.** Example: Word CT assessment

Word CT Assessment			
Product Model	RZ39-0350	LG ULTRAGEAR	Hisense-34G6K-PRO
Resolution	2560*1440	3840*2160	3440*1440
refresh rate	144Hz	120Hz	180Hz
Word CT JND	3	4	2
TXT CT worst pattern judge	2.9	6.2	3.37
Mix color TXT CT COLOR DEV	10	10	1
Total.	4.36	6.08	2.348

**5. Conclusion**

In this study, we commenced from the fundamental principles of textual crosstalk, delving into the causes and corresponding phenomena that give rise to this effect. We designed distinct patterns that enable the observation of textual crosstalk across various architectures. Furthermore, we refined the grading of subjective perceptions, allowing for an objective, nuanced, and precise articulation of the textual crosstalk severity in test samples.

**6. References**

1. Liu J, Xiao J, Zhang S, He X, Yu Y, Zhao B. Mechanism and Improvement on Horizontal Crosstalk in 8K a-Si TFT-LCD. In: Proceedings of the 2021 IEEE 4th International Conference on Electronics Technology (ICET); 2021. p. 360-363. Available from: <https://api.semanticscholar.org>