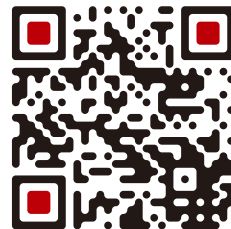


TECHNICAL ARTICLE

Fine Pitch LED Display

Possible Problems and Driver IC Solutions



EXTEND YOUR LED VALUE



Macroblock's MBI515X Series LED Driver ICs Solve the Seven Common Problems for Fine Pitch LED Display

Ghosting Effect / Non-uniformity at Low Grayscale
Dim Line at the First Scan Line / Color Shift at Low Grayscale
Gradient Dim Line / Cross Effect Caused by Failure LED
High Contrast Brightness Interference

Fine Pitch LED Display Possible Problems and Driver IC Solutions

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Bigger is no longer necessarily better. A look at exhibitions in the last couple of years reveals that most exhibitors are opting to offer an experience of clear, refined, close-distance displays. Vendors' booths were no longer just product exhibition areas, but instead contained areas that simulated real scenarios, such as conference rooms, central control rooms, and banquet halls, allowing buyers and other visitors to easily appreciate the display end customers' applications. In conjunction with special mechanism designs, many displays for specific applications will become part of our life experiences. These products—including LED TVs, LED advertising panels—were the focus of this year's show.

In the industry, displays with a pixel pitch of less than 4 mm are known as "fine pitch displays," and displays with a pitch of less than 2.5 mm are called "super fine pitch displays." In the remainder of this article, P2 refers to a pixel pitch of 2 mm, and P2.5 refers to a pitch of 2.5 mm, and so on.

From a marketing perspective, fine pitch displays were indisputably the focal point many display vendors' products. P3.9 specification displays were applied to products with a viewing distance of approximately 2-3 m, such as upright advertising panels that can be placed on the ground and can replace traditional advertising light boxes and shop windows. These products boasted vibrant colors, clear images, and sufficient brightness. P2.5 specification displays attracted the most attention in the fine pitch display category. This was chiefly because P2.5 products can readily meet users' needs when used indoors at a viewing distance of 1-2 m. However, there were differences between different vendors' products in terms of refresh rate, color performance (grayscale), contrast, and image detail at low grayscale. Companies also showed their fine pitch display product R&D for specifications of P2 and below at the trade show. There were numerous products with P1.9/P1.8/P1.6/1.4/P1.2/P1.0 specifications, and almost every vendor tried to show their new products on display. However, the best way to distinguish different vendors' achievements in terms of refresh rate, grayscale, and low grade level performance was in the P2.5 product category.

A display's display? Performance is actually connected with its driver ICs, and this is especially true in the case of fine pitch displays.

Why does driver IC have such a big influence on image quality? The reason lies in the display's "time-multiplexing" design.

A fine pitch display must accommodate more elements within the same unit area than a large pitch display, and the front of the module must contain even more LEDs. Taking a P2.5 design with the LED and driver IC on the same side as an example, a one square meter module must accommodate 160,000 SMD LEDs, and the back of the module must have elements such as driver ICs and current setting resistors. A static design would require 30,000 16-channel driver ICs and 30,000 current setting resistors. When routing, an increased number of PCB layers, and increased cost are taken into consideration, we find that a time-multiplexing design is essential. A time-multiplexing design makes use of a single driver IC to turn on more LEDs, conserving the driver IC's layout

area. Because of this, the smaller the pitch, the greater the number of time-multiplexing in the design. P2.5 displays generally adopt a 1:16 time-multiplexing design, and 2 mm displays and below adopt time-multiplexing above 1:16.

While a time-multiplexing design reduces layout area and number of elements that must be used, it also has the side effect of reducing the refresh rate. The refresh rate is defined as the reciprocal of the amount of time needed by all LEDs to be lit once (in units of Hz). In a time-multiplexing design, after the first row of LEDs is lit, the second row of LEDs is then lit, and so on, up until the final row is lit, and scanning then returns to the first row. Because of this, when the number of scan lines is doubled, the time needed to light up all LEDs will also double, and the refresh rate will be halved. This implies that the greater the number of time-multiplexing in a design, the more challenging it is to achieve a high refresh rate. The use of a driver IC with an embedded SRAM can increase the refresh rate by shortening the time needed to transmit grayscale data. And if a driver IC supports GCLK multiplier technology, the refresh rate can be doubled again. Test data for the MBI5152 indicates that a refresh rate of roughly 3,000 Hz can be achieved in the case of P2.5 specifications, 16-scan, and 14-bit grayscale display.

The display performance of low grayscale images is another key issue for fine pitch displays. The display performance of low grayscale images refers to the ability of an LED display to perform rich color-depth images under conditions of low brightness and a low grayscale level. Since end users' applying fine pitch displays are generally used indoors, where high brightness would not be suitable for close viewing, the display brightness is ordinarily less than 600cd/m². Because of this requirement, a low-brightness and rich color-depth image display capability is needed in this type of application.

The most effective way to verify the display performance of low grayscale images is to display special test patterns on the LED display, such as a diagonal stripe pattern, single grayscale patterns in different colors, and single-color patterns with grayscale varying from zero to high levels. These test patterns allow verification of display performance of low grayscale images in a fine pitch display. Macroblock has introduced MBI515X driver ICs to resolve the seven major problems.

Problem 1: Ghosting Effect

The phenomenon of ghosting effect is one of the first problems identified in low grayscale images in time-multiplexing designs. It is primarily attributed to the charging/discharging of parasitic capacitance in PCB during row/column changes on screen, which causes LEDs to light up when they should not. The phenomenon is even more pronounced on a diagonal stripe test pattern. The phenomenon of ghosting effect can be divided into upper ghosting effect and lower ghosting effect.

A. Upper Ghosting Effect

During the row-by-row scan, as shown in Figure 1, if Row 1 is conducting, LED1 lights up and LED3 does not. Meanwhile, Cpar1 in Row 1 is charged. When Row 2 is conducting, if only LED4 is supposed to light up but LED3 lights up as well because of parasitic capacitance in the rows of PCB, Cpar1 is retained by charging VLED1 and the discharge path formed by LED3 at row change leads to Driver-IC lighting up the LED. This is known as upper ghosting effect.

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The solution is to utilize an external discharge circuit to create a discharge path for the parasitic capacitance in the rows of PCB, as shown in Figure 2. Parasitic capacitance will be discharged before the row change, which will solve the problem of discharging through LEDs and in turn eliminate ghosting effect.

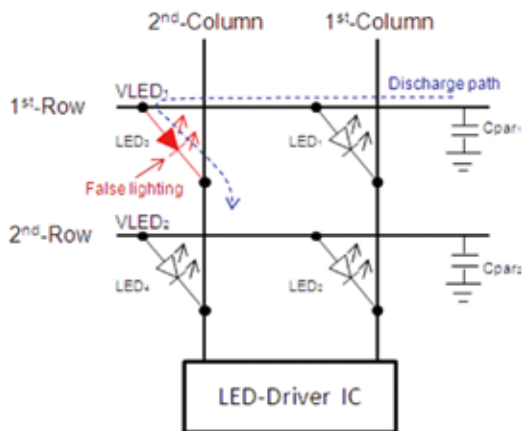


Figure 1 Upper ghosting effect

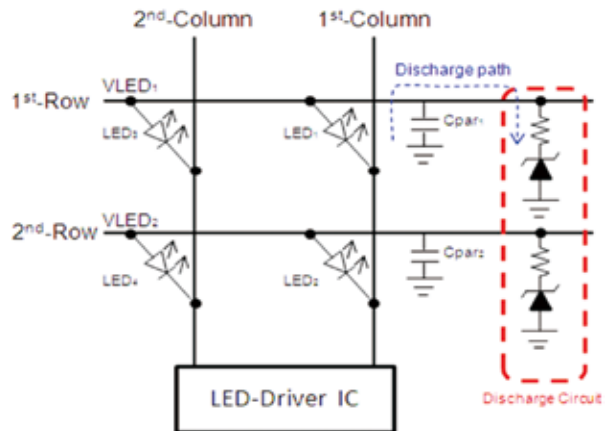


Figure 2
Discharge circuit structure of upper ghosting effect

B. Lower Ghosting Effect

During the row-by-row scan, as shown in Figure 3, when Row 1 is scanned, Column 1 is conducting and LED1 lights up while Column 2 is turned off and LED3 does not light up, C_{par1} will discharge through Row 1. When changed to Row 2, only LED4 is supposed to light up as Row 2 is conducting, but LED2 lights up at the same time. This phenomenon is explained by the fact that parasitic capacitance in columns of PCB, C_{par1} , has been discharged to lower voltage levels when Row 1 is scanned and so changing rows creates a charging path via LED2 to Driver-IC to light up the LED. This is known as lower ghosting effect, and the waveform is shown in Figure 4.

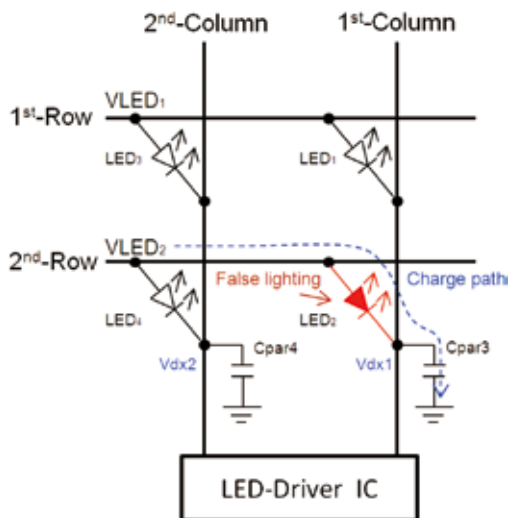


Figure 3 Lower ghosting effect

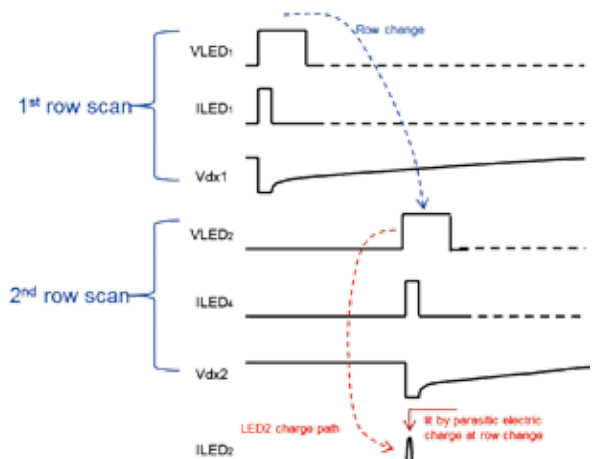


Figure 4 Lower ghosting effect waveform

Through the built-in pre-charging circuit in the display driver IC, as shown in Figure 5, charging can be performed prior to row changes during a scan by charging the parasitic capacitance in columns of PCB to increase the column voltage, which will cut off the charging path for column capacitance at row change and eliminate lower ghosting effect. The principle of eliminating lower ghosting effect is illustrated in Figure 6.

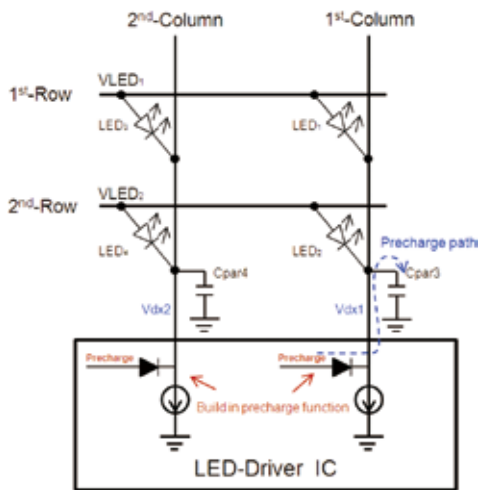


Figure 5
Built-in pre-charging circuit in display driver IC

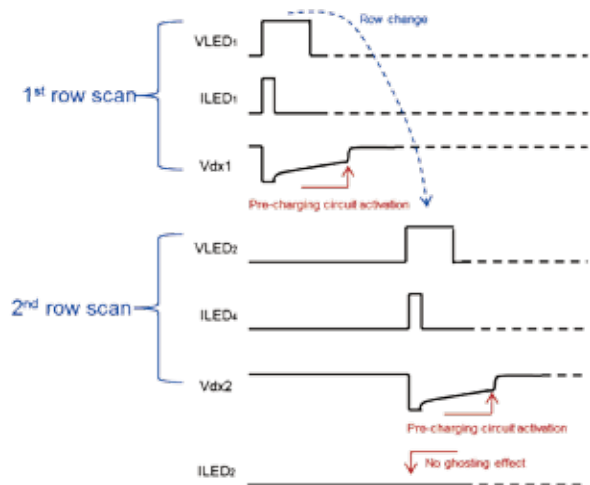


Figure 6
Principle of adding pre-charging circuit to eliminate lower ghosting effect

Observations of the display above show clear lower ghosting effect in Figure 7 and pre-charging technology eliminating ghosting effect in Figure 8.

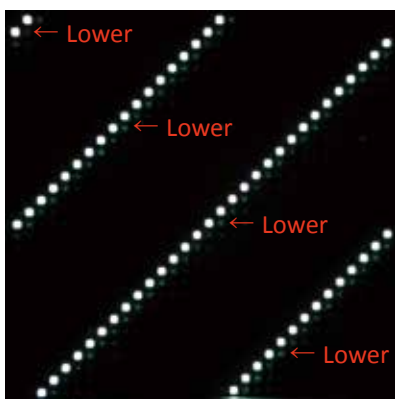


Figure 7 Clear lower ghosting effect



Figure 8
Pre-charging technology eliminating ghosting effect

However, activating pre-charging to eliminate ghost images can lead to other problems.

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Problem 2: Color Shift at Low Grayscale

The test pattern used in Figures 9 and 10 consists of a low grayscale white pattern. When the pre-charging function is turned on, we can see that the module appears reddish. Driver ICs in the MBI515X series are able to correct color shift. Figure 10 shows use of the MBI515X series to eliminate color shift when pre-charging has just been turned on.



Figure 9

Reddish module when pre-charging is turned on



Figure 10

Low grayscale white pattern disappears when pre-charging is turned on

Problem 3: Non-uniformity at Low Grayscale

Non-uniformity is especially easy to see under low grayscale conditions, which imposes very stringent uniformity requirements on driver ICs. Pre-charging will be performed to increase voltage levels in the rows in order to eliminate lower ghosting effects. However, this method will create the problem of non-uniformity in areas. The effect is more detectable by the naked eye when displayed in low grayscale images. Uneven areas in medium and high grayscale images may be caused by differences in PCB allocation and non-uniform voltage levels due to differences between driver ICs. A low grayscale monochrome test pattern was used in Figures 11 and 12. In Figure 11, the lines crossing in the center divide the screen into four sections, and it can be seen that these sections have uneven brightness. Each section contains 16 x 16 LEDs, and three driver ICs control the RGB LEDs. But because the drive ICs have poor uniformity, the problem of uneven brightness at IC controlled area occurs.

As shown in Figure 11, the brightness on the left differs from the brightness on the right at the IC controlled area.

Figure 12 shows a module using MBI515X series, which can be seen to have even brightness throughout the module, reflecting high uniformity of driver ICs.

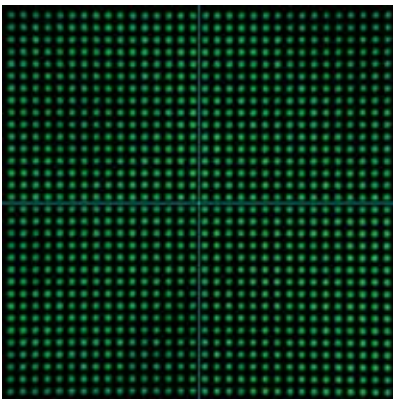


Figure 11 Non-uniformity at IC controlled area

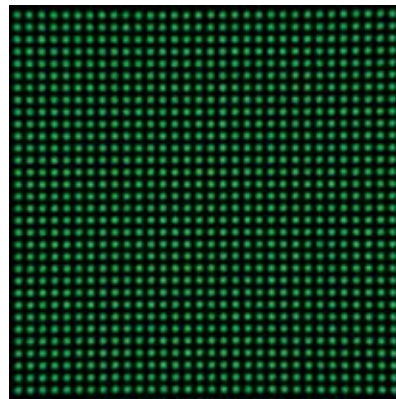


Figure 12 Even brightness

Another phenomenon of uneven brightness occurs at the pixel level, and is known as the blurry screen effect. The electrical properties of LED particles play a role in the production process. Shifts between different batches of production will cause variations in LED properties for different batches. There will be deviation between LED particles in the same patch. The sum of such characteristic deviation is the cause of the blurry screen effect. As shown in Figure 13 and 14, the same source materials are displayed in full screen. The brightness of individual pixels differs and is distributed randomly as shown in Figure 13, and does not show significant improvement even under increased brightness. Brightness calibration is an effective way to fix the blurry screen effect. However, the cost of brightness calibration is high and recalibration will be required for aged LEDs. In other words, recalibration will be needed at regular intervals, creating higher maintenance costs. MBI515X utilizes built-in brightness equalization to create more even, smooth screen brightness as shown in Figure 14.



Figure 13
Randomly distributed image results from
the individual pixels with different brightness



Figure 14
Even image results from
the individual pixels with the same brightness

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Problem 4: Dim Line at The First Scan Line

The way a scan type display works is to light up LEDs line by line, as shown in Figure 15. If LEDs in a frame are off for longer than they are conducting, parasitic capacitance in the PCB module will lead to increased column voltage. In particular, the column voltage when Row 1 is scanned and conducting will be higher than the column voltages when the other rows are scanned. As a result, the LED current when Row 1 is scanned and conducting will fall and the LED brightness of Row 1 will fall as shown in Figure 16. It can be observed on the actual display that Row 1 is a dim line.

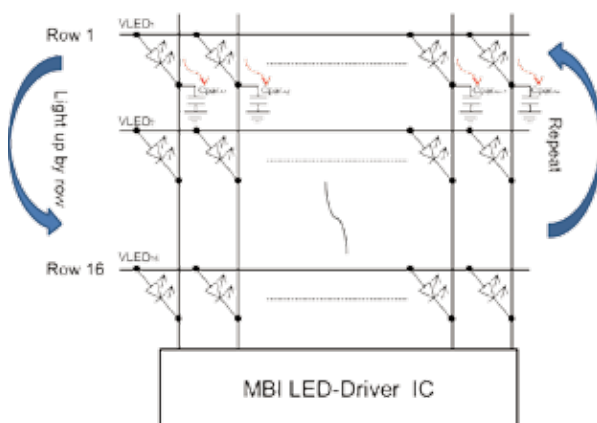


Figure 15 How scan type display works

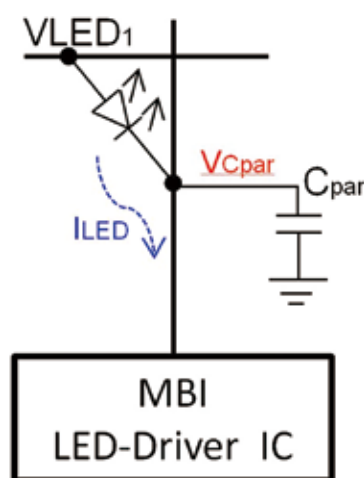


Figure 16

Impact of parasitic capacitance in PCB on row

The low grayscale compensation technology is used during a row-by-row scan to compensate the current in Row 1 and supplement current loss caused by the parasitic capacitance in the PCB module in order to eliminate the dim lines in Row 1 on the scan type display. Figure 17 shows the ideal LED current waveform, Figure 18 shows the waveform under the influence of parasitic capacitance in the PCB module, and Figure 19 shows the result after compensation proposed in this article.

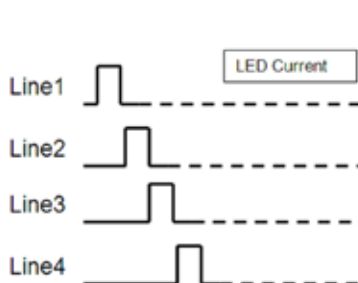


Figure 17 Ideal LED current

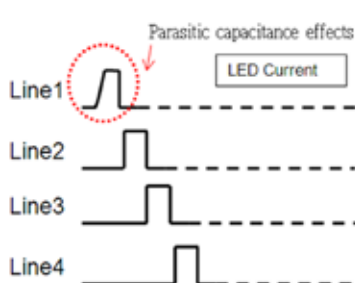


Figure 18 Actual LED current

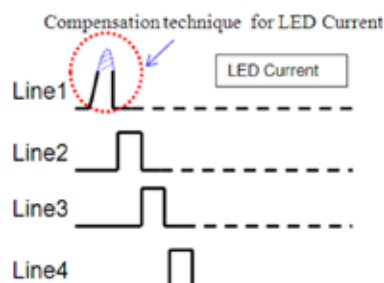


Figure 19
Compensated LED current technology

Figure 20 shows a 32 x 32 16-scan module with a low grayscale monochrome test pattern. You will notice that the first scan line in the upper and middle parts of the figure are abnormally dark; this phenomenon is known as the dim line. Observations of the display above show dim lines in Figure 20. Figure 21 shows how darkening of the first scan line has been eliminated through use of a MBI515X driver IC, and it can be seen that the dim line phenomenon has been eliminated very effectively.

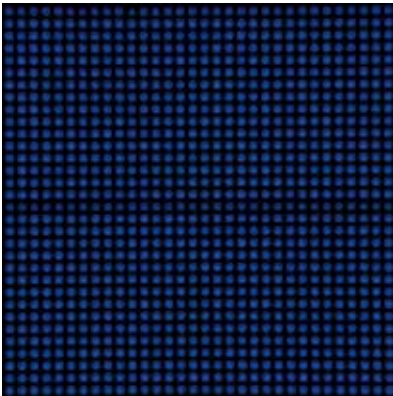


Figure 20 Problem of dim line at the first scan line

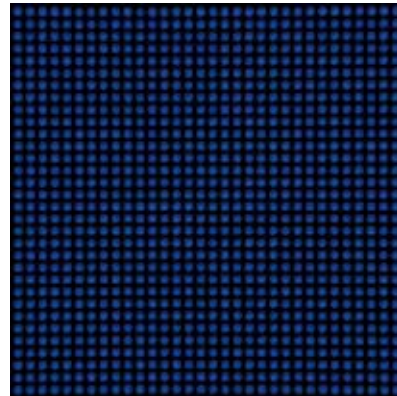


Figure 21
Compensated current technology eliminates dim line

Problem 5: Gradient Dim Lines

The test pattern in Figure 22 consists of a white gradient pattern. The pattern increases from a 0 gray level to a 256 gray level toward the right, and is used to check the smoothness, linearity, and contrast of the display's color scale gradient, enabling whether the display can accurately express the details of images when used for video displays. When using this test pattern, the dim line at first scan can be seen very clearly under low grayscale. Figure 23 shows an image of the actual display during testing with the MBI515X module. It can be seen that smooth variation in gray level and high contrast are maintained while eliminating the gradient dim lines.

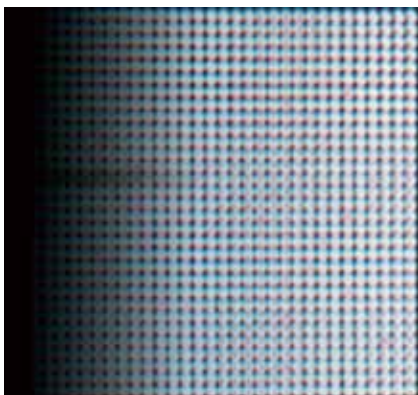


Figure 22 Clear gradient dim lines

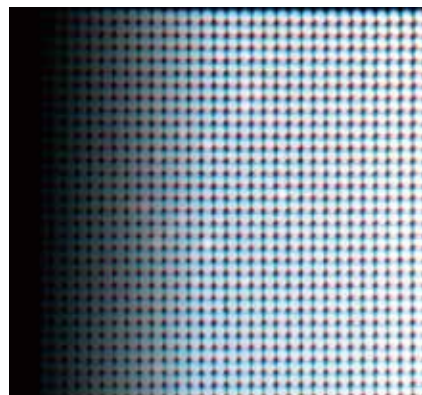


Figure 23 Gradient dim lines are eliminated

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Problem 6: Cross Effect Caused by Failure LED

The cross pattern formed by the failure LED in an LED display can be very confusing for display end users. Especially in the case of time-multiplexing designs, a cross pattern may be formed when LEDs extending in the horizontal direction are mistakenly lit, and mistakenly-lit LEDs in the vertical direction extend in proportion to the number of scan lines. Since fine pitch displays are typically designed with more than 16 scan lines, as soon as a bad pixel occurs in the LED, a clearly-visible cross pattern will appear, creating a display defect. The test pattern used in Figure 24 consists of a white monochrome oblique scan pattern. A bad pixel in the LED has led to a blue light LED malfunction; the bad pixel consequently appears yellowish, and a cross with the bad pixel at its center is visible. Figure 25 shows an actual test pattern in which the cross pattern has been eliminated; it can be seen that the cross phenomena has disappeared completely.

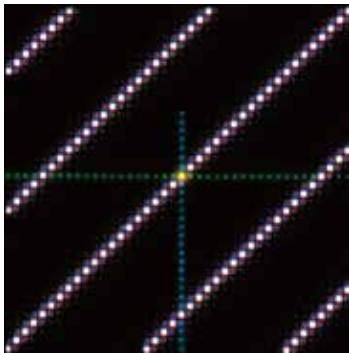


Figure 24 Cross pattern caused by failure LED

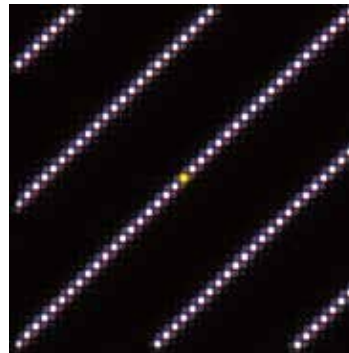


Figure 25 Cross pattern is eliminated

Problem 7: High Contrast Interference

A lately found problem is issued here as "high contrast interference". When a high brightness pattern displays low brightness patterns neighborhood, color shift or brightness down happens at low brightness pattern due to the mutual interference of output channels. Since the interference always shows on the connection area between high brightness and low brightness patterns, we named the problem as "high contrast interference". "high contrast interference" can be usually aware of images like white text with dark backgrounds, or the shadow of objects, such as shadow at edge on human face. The pictures shown below left is the facts of "high contrast interference", where we can see the color shift and brightness down at edge on human face both. The picture on the right is the fact of Macroblock ICs fixed "high contrast interference" problem.



Figure 26 Fact of high contrast interference



Figure 27 High contrast interference is much improved

Looking back on the development of full-color LED displays, early LED displays had poor luminous efficiency, and were chiefly used in outdoor applications. As a result, display manufacturers made the pursuit of high brightness as their first priority. Today, as fine pitch displays begin to enter the market, displays are increasingly being used indoors, and end users' application needs are changing. Not only do broadcasting rooms, control centers, and indoor advertising panels require a high refresh rate and high grayscale, they also require an excellent low grayscale effect when viewed at a close distance. These requirements have increased the challenges facing display manufacturers, and have established new thresholds in such areas as electronic design, manufacturing technique, and cost control. Nowadays, only manufacturers willing to commit themselves to intensive R&D will meet the test of the market. With regard to the new challenges brought by fine pitch display products, Macroblock has already developed display driver IC technologies, and is tirelessly developing new technologies that offer optimal display driver solutions and will enable customers to resolve practical issues in fine pitch display and achieve profits in the fine pitch display market.

To know more about the 7 problems and solutions of fine pitch LED displays, please contact Macroblock at marketing@mblock.com.tw

Reference Material

1. Challenges and Solutions of Full-Color Indoor LED Displays(Kangbin Sun / Evan Wang, 2013)
2. Looking at "Core" Technical Standards for LED Display Drivers from the Perspective of LED China 2014 (Chung-Ta Tsai, 2014)

About Author

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Product Director of Technical Marketing Department, Macroblock, Inc. He is in charge of product definition, product development and sales marketing, includes MBI515X and more. Chung-Ta Tsai was a R&D engineer in Macroblock to develop diverse LED driver ICs. His interested fields are mixed-mode/ analog IC design, switching power and LED applications. He also owns patents for EMI elimination (US).

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