White Paper

Color Uniformity Compensation Function of ColorEdge CG221

CONTENTS

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1 Preface

In recent years, the monitor has gained importance with the widespread adoption of the digital workflow in the printing and graphics market. In particular, a higher level of display performance is required for softproofing, which allows previewing a print output on a monitor screen, ensuring fewer color proofs and a faster workflow.

To meet the demands of the printing and graphics market, we have developed various technologies for better color reproduction, optimization of grayscale characteristics, exclusive calibration software (ColorNavigator), and incorporated these technologies in our ColorEdge series of monitors.

As the ColorEdge series has received increasing recognition in the market, we have received further demands for higher quality in display performance. One of the strongest demands is the color uniformity on screen. In response to this demand, we have developed a uniformity compensation technology and achieved uniform levels of color across the screen, which has been all but impossible with LCD monitors alone. Incorporating this color uniformity technology, the ColorEdge CG221 can display images on the screen with overall uniformity of brightness and color throughout the entire screen at an unprecedented level.

In this white paper, we will clarify our view on the color uniformity function required for a graphics monitor and how we have realized this function on the ColorEdge CG221.

ColorEdge CG221

2 Influence of Color Uniformity on Image Quality

2.1 Color Uniformity

Color uniformity refers to the uniformity of color tint on screen. On-screen uniformity involves color uniformity and brightness (luminance) uniformity, which are usually discussed separately. However, in this paper, color uniformity refers to the uniformity of both color and brightness.

A monitor screen usually looks uniform. However, with a closer look, a monitor screen is not uniform in brightness or color, being brighter in the center and darker towards the corners or having colored spots. In addition, when comparing a solid white screen and a solid gray (midtones or low tones) screen, these screens have different non-uniformity states. This means that gamma values vary depending on the area of a screen. Fig.1 and 2 are actual uniformity measurement data for reference, which show that delta E values at the center and the periphery of the monitors are very different.

* Delta E: Delta E is the calculation result of difference in brightness and chromaticity between two points. The larger numbers will result in more noticeable color change. If delta E is around 1, it is generally believed that most viewers will not notice the difference between two colors.

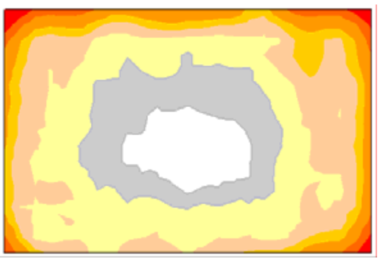


Fig.1: Delta E on screen (255th gray level)

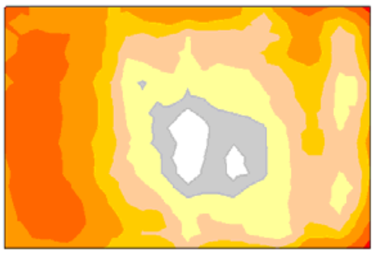
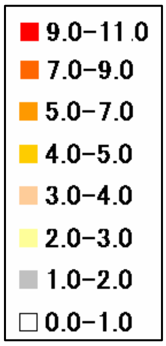


Fig.2: Delta E on screen (128th gray level)



Delta E Scale

2-2 Influence of Color Uniformity on Screen

In this section, we look at problems that occur on a monitor where there are variations in chromaticity, brightness and gamma by area. One of the problems is the color difference in some areas of a screen. If a monitor displays an image with the right area of the screen colored yellow like Fig.4, for example, the viewer will consider that the image colored yellow at the right corner is the correct image.

Fig.3: Correct image

Fig.4: Yellow at the right corner of the screen

Other problems occur when comparing colors of images, such as by displaying the same images next to each other on a screen. Taking Fig.5 for example, the left image is yellowish, and the right one is reddish. Therefore, the color uniformity imperfection affects fair comparison of images on a screen.

Furthermore, gamma values can vary from one area of the screen to another. If gamma values are different at right and left sides of the screen, even if the screen is calibrated at the center, the same images are displayed in different brightnesses and colors as shown in Fig.6.

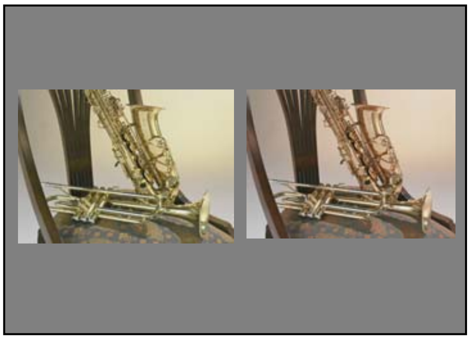


Fig.5: Different color
at right and left sides of screen

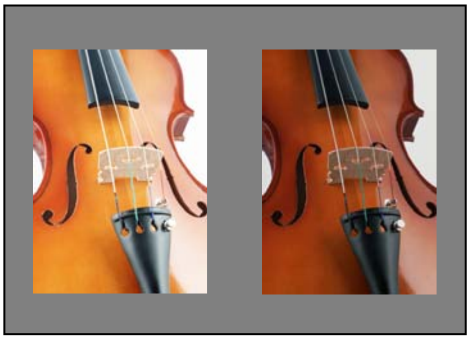


Fig.6: Different gamma values
at right and left sides of screen

As explained with the three examples above, if color uniformity of a monitor screen is imperfect, the viewer will be unable to accurately check and correct colors on screen.

3 Causes of Color Non-Uniformity

In this section, we briefly explain the causes of the color non-uniformity.

3-1 Effect of Panel Structure

Non-uniform light from backlight is one of the causes for non-uniformity of color. Backlights are located at the back of an LCD panel as shown in Fig. 7. The direct light from backlights becomes non-uniform due to the radiance of the backlight and the location of the backlight, though there is variation between LCD panel types. In addition, the light reflected from other materials such as a light reflector is not uniform. Both types of light are designed to be uniform, but making them completely uniform is extremely difficult.

Fig.7: Structure of an LCD monitor

3-2 Effect of Liquid Crystal Cell, Light Guide Plate and Other Optical Sheets, and Color Filter

The uneven thickness of a liquid crystal cell is also a cause of color uniformity imperfection. A liquid crystal cell has a gap between extremely thin glasses, and the gap spacing may become uneven. In addition, a built-in light guide sheet and other optical sheets and a color filter may influence color uniformity.

3-3 Effect of Liquid Crystal Driving Mechanism

The mechanism driving liquid crystal molecules influences color uniformity. A wide LCD monitor, which must drive liquid crystal molecules arranged on the whole landscape screen area, especially has difference in the driving timing between the left side and the right side of the screen. The result is color uniformity imperfection.

4 Measurement Examples of Digital Color Uniformity Compensation

Dealing with the problem of color non-uniformity on screen, EIZO has developed the digital color uniformity compensation function and incorporated it into the new ColorEdge CG221. This function compensates brightness and chromaticity across the screen at each of all grayscale levels.

The following figures compare the color uniformity before and after compensation. It is clear that the color uniformity on screen is dramatically improved to a fairly uniform level, which has been all but impossible with LCD monitors. The following figures show that color uniformity over almost the whole screen area is improved to delta E 1 to 2 or below at each grayscale level. Thus we can conclude that the existing screen non-uniformity problem has been almost completely solved.

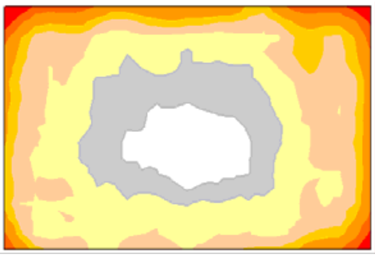
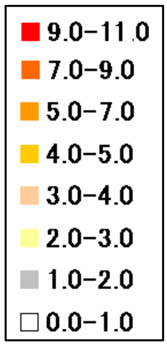


Fig. 8: At 255th gray level (before compensation)

Fig. 9: At 255th gray level (after compensation)



Delta E Scale

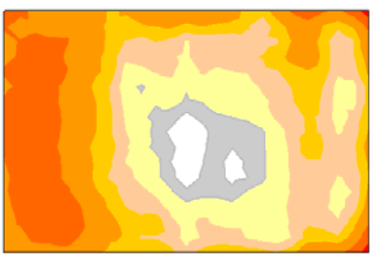


Fig. 10: At 128th gray level (before compensation)

Fig. 11: At 128th gray level (after compensation)

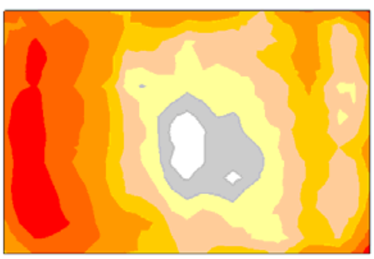


Fig. 12: At 64th gray level (before compensation)

Fig. 13: At 64th gray level (after compensation)

5 Digital Color Uniformity Compensation Mechanism

In this section, we explain how the digital color uniformity compensation function works on the ColorEdge CG221.

5-1 Uniformity Compensation Across Screen

To correct a screen, for example at white of the gray level 255, both brightness and color need to be compensated. Once these compensations are done, the screen is uniform in brightness and chromaticity. In the actual compensation procedure, brightness and chromaticity are compensated in all areas of a screen on each monitor.

<Brightness Uniformity Compensation>

If brightness is not uniform on a screen like Fig. 14, the brightness of the non-uniform areas are compensated to match the surrounding areas. When this procedure is conducted over the whole screen, the screen becomes uniform in brightness.

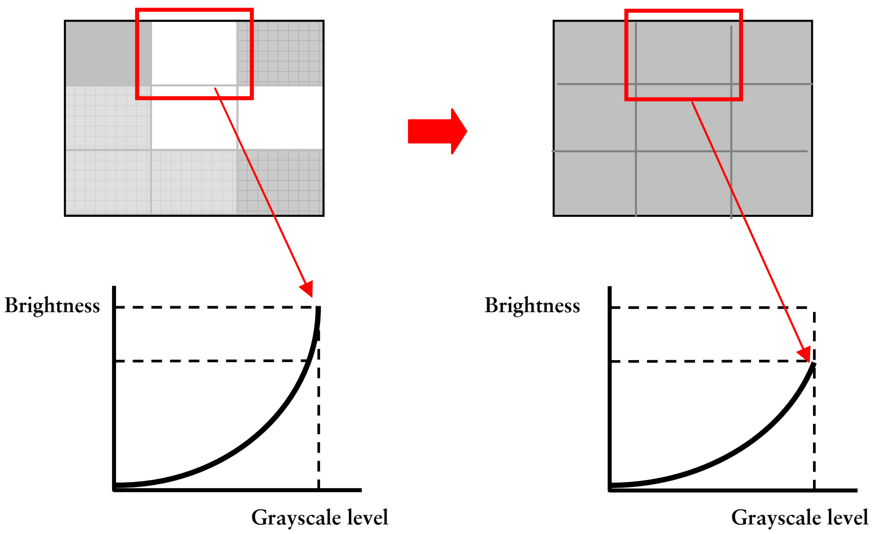


Fig. 14: Brightness Uniformity Compensation

<Chromaticity Uniformity Compensation>

Next, chromaticity uniformity compensation is conducted. Simply achieving brightness uniformity does not guarantee color uniformity, because color on the screen is usually not uniform to begin with. The chromaticity uniformity compensation is conducted by correcting the RGB balance of a non-uniform area to be closer to that of the screen center. In the case of Fig. 15, the bottom right area of the screen has stronger green and blue than the screen center, and each of these colors are compensated. When this procedure is conducted on the whole screen area, the screen becomes uniform in chromaticity.

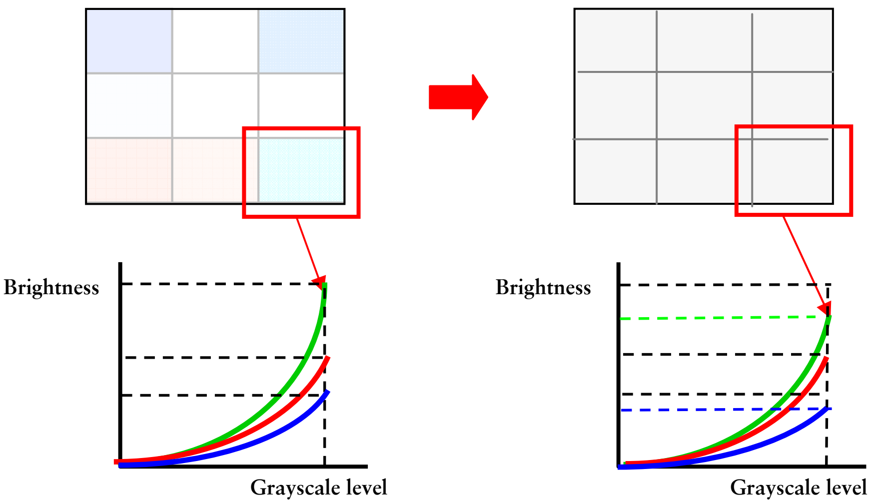


Fig. 15: Chromaticity Uniformity Compensation

5-2 Uniformity Compensation At Each Grayscale Level

In section 5-1, the uniformity compensation procedure is explained taking the example of the 255th gray level. However, as is commonly known, actual image data consists of not only the 255th level but also other levels between 0 and 254. The digital color uniformity compensation function corrects uniformity at each of almost all grayscale levels to realize ideal screen display performance.

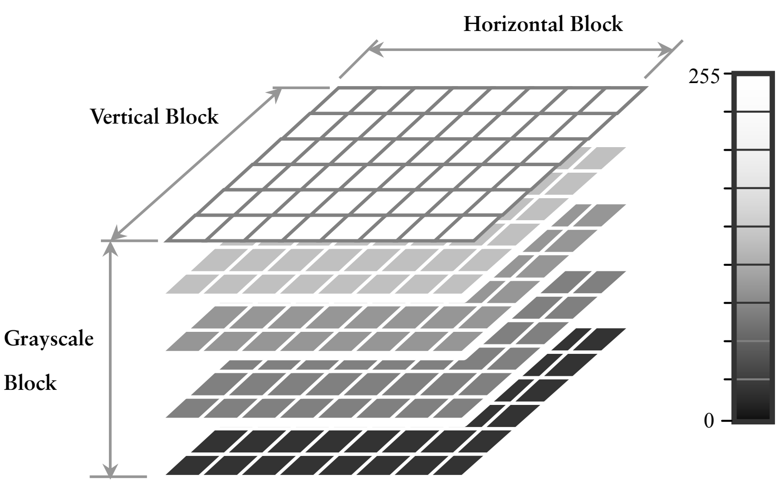


Fig. 16: Uniformity Correction at Each Grayscale Level

In this process, the screen at each of all grayscale levels becomes uniform in brightness and chromaticity, which results in a uniform gamma value at any area on the screen.

5-3 Highly Accurate Compensation with 12-bit LUT (Look-Up Table) & 16-bit Internal Calculation Capability

The compensation across the screen at each of all grayscale levels could be realized with the previous system with 10-bit LUT and 14-bit internal calculation capability in principle. However, in reality, having noticeable color seepage and other flaws, the resulting images were not sufficient enough for the practical use. To realize the color uniformity compensation function responding to this problem, we have developed a new ASIC (Application Specific Integrated Circuit) exclusive for color compensation, which alone successfully conducts the compensation algorithm explained above and achieves higher compensation accuracy (Fig.17).

Fig. 17: New Color Compensation ASIC

Although working on very much the same compensation principle as that of previous ColorEdge models, the new compensation system (the new color compensation ASIC) includes the color compensation procedure in the compensation flow, incorporates 16-bit internal calculation capability upgraded from the previous 14-bit, and supports a 12-bit LUT increased from the previous 10-bit LUT. These improvements have contributed to improved data conversion accuracy at whole compensation flow, resulting in more accurate grayscale rendering capability at all levels including midtones. Fig. 18 shows the roles of the different sections and the signal flow.

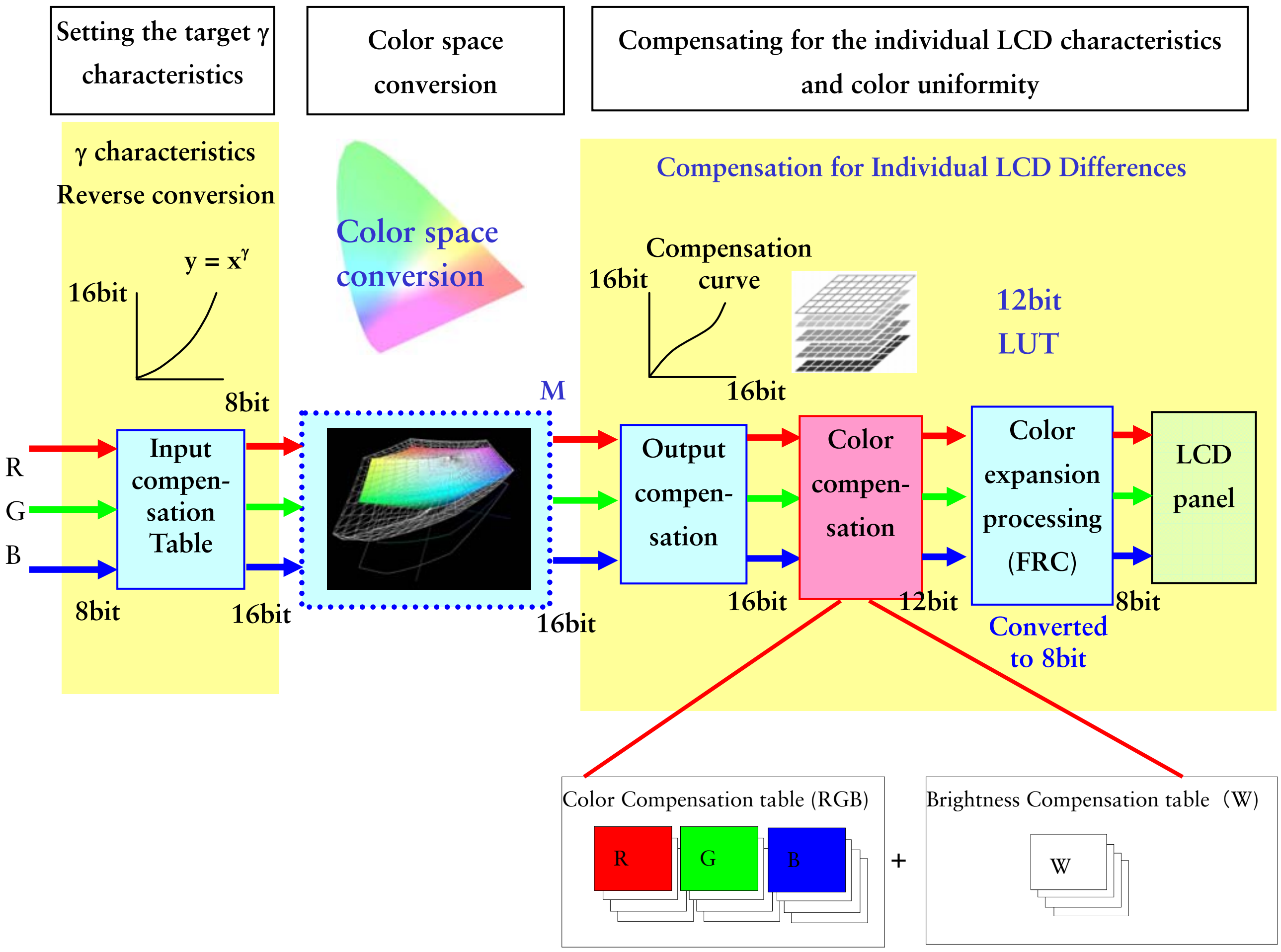


Fig.18: Compensation Flow

Setting the target γ characteristics

Assuming that there are no differences between individual LCDs (that the γ characteristics are optimal), the target γ characteristics (e.g., 1.8) are determined mathematically.

Color space conversion

As simply setting the target γ characteristics does not yield the correct color temperature, the color temperature is determined mathematically. The resulting color temperature is closer to the target due to improved internal calculation accuracy (16-bit processing) and higher LUT accuracy (12-bit LUT).

Compensating for the individual LCD characteristics (Grayscale and Color Uniformity Compensation)

This step absorbs any individual differences that originally existed in the LCD panel and ensures that smooth grayscale characteristics are obtained. At this stage, color uniformity compensation is also conducted. With the use of 12-bit LUT (16-bit internal calculation capacity), a highly accurate compensation becomes available.

6 Summary

This section summarizes the technologies comprising color uniformity compensation.

1. Development of the exclusive color compensation ASIC

Using the new ASIC developed exclusively for color compensation, color uniformity compensation has been realized. The color uniformity compensation is conducted at all areas of screen at each of all grayscale levels on each monitor.

2. Realization of 12-bit LUT and 16-bit internal calculation capacity with the use of the exclusive color compensation ASIC

12-bit LUT and 16-bit internal calculation capacity, which are improved from 10-bit LUT and 14-bit internal calculation capacity on the previous models, have allowed to improve the accuracy of the color uniformity compensation up to the practical level.

3. Establishment of the compensation algorithm

The compensation algorithm as well as the exclusive color compensation ASIC have been developed. In addition, the accumulation of the know-how for higher compensation accuracy has realized the ideal screen.

From the above, with the further advancement in the ColorEdge CG221, it is clear that ColorEdge monitors have taken a significant step closer to being the ideal color management monitors for printing workflows.