

Introducing BrilliantColor™ Technology

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Abstract

This white paper will discuss Texas Instruments BrilliantColor™ technology. This technology uses innovations in image processing to improve the optical efficiency of DLP® projection systems while expanding the capability of current RGB color wheels. BrilliantColor™ technology may also be combined with new color wheel designs that can expand beyond traditional 3-color systems, enabling the utilization of wide color gamuts on DLP display systems. The combined effect is that the Original Equipment Manufacturer (OEM) now has the opportunity to provide a brighter display that utilizes a customized color gamut that is not available on competing technologies.

Introduction

Historically, most display devices would render a scene using the three primary colors, red, green, and blue. The combination of these three colors allows one to display any color that is within the triangular region bounded by those three colors (reference Figure 1). This limits available colors that can be displayed,

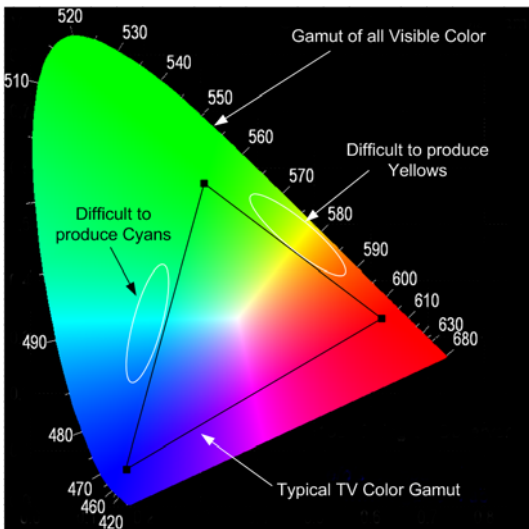


Figure 1 -- Color Gamut of a Typical Television or Projector

making it difficult to display brilliant yellows and cyans that are commonly found in natural scenes.

The color gamuts typically found on all current consumer display systems trade off having a wide color gamut with brightness. One can increase the size of the color gamut by increasing the saturation of the primaries. Saturated primaries move the red, green, and blue points of the triangle closer to the edge of the visible color spectrum and cover a greater area of the visible color spectrum. Because the saturated primaries typically are not as bright, the use of saturated primaries reduces the overall brightness of white tones and saturated colors. By adding yellow, cyan, and magenta colors to the rendering of the image, one can maintain bright white points while providing deeper red, green, and blue color points.

The three color gamut has been used quite successfully for the Cathode Ray Tube (CRT) color displays. The first DLP® display systems also utilized a similar approach whereas the image is split into its red, green, and blue components for display on the digital micro-mirror device (DMD).

Factors Impacting Display Brightness

There are several factors that affect the end brightness of the display in lamp based display systems. A typical DLP® Display optical path is shown in Figure 2.

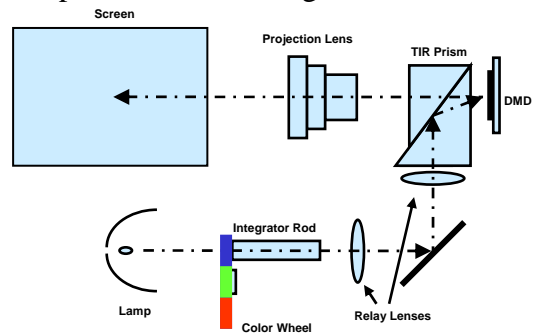


Figure 2 – DLP® Optical Path

Items such as lumens collected out of the lamp, optical system efficiency, color wheel efficiency, and screen efficiency impact the brightness of the display. The screen brightness is simply the efficiency of the optical system multiplied by the collected lumens and the screen gain. Improving any of the efficiencies in the optical path will result in an improvement of the screen brightness.

Improving Illumination Efficiency

Lamp based displays render an image by splitting the white spectrum of the lamp into the three primary colors, red, green, and blue. In order to achieve the standard color gamut required for TVs and projectors, the generation of the red, green, and blue light components does not utilize the entire energy spectrum available from the lamp. This light loss is a result of the fact that parts of the lamp energy are not contained within the red, green, and blue filters used to render the image (reference Figure 3).

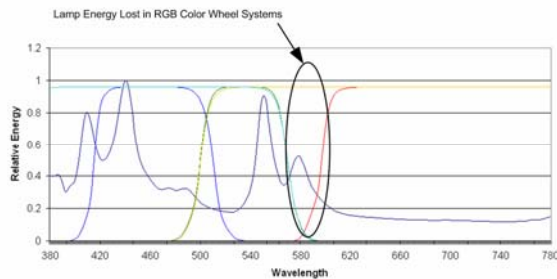


Figure 3 – Spectral Energy Distribution of a typical Lamp

BrilliantColor™ technology resolves this problem through the utilization of additional color filters. In Figure 3, there is a significant amount of lamp energy that is not utilized at the 580nm wavelength. This energy can be recaptured through the use of a yellow filter. Also, a cyan filter will improve the efficiency in the 500nm region. Designing a projection system that uses a 5-color illumination system can improve the end brightness by as much as 50%. Table 1 shows the improvement that can be gained

in a DLP® display system using the new .45 720p DMD and a 5-color wheel.

	Common Color Wheel	5 Color Wheel
Collected Lumens at the DMD	3375	3375
Optical Efficiency	35.8%	35.8%
Color Wheel Efficiency	16.5%	24.7%
Screen Gain Factor	4.7	4.7
Screen Diagonal	60	60
Luminance (Nits)	300	450
Luminance Gain	baseline	50%

Table 1 -- Luminance Gain from BrilliantColor™ in an Example .45 720p system

Improved Color Gamut

In addition to improved system illumination efficiency, BrilliantColor™ technology also allows for a much broader color gamut. The color gamut of a red, green, blue display is defined as the area of colors bounded by the triangle whose points are defined by the colorimetric settings of the red, blue, and green filters. Any color that can be displayed on the system is some combination of the red, green, and blue colors. Though this color space is suitable for many applications, it does not allow for the creation of vivid colors such as yellow and cyan. The reason for this is that the vivid yellow (or cyan) that we frequently see in nature is outside of the area bounded by the triangle. Adding additional color to the rendering engine allows us to expand the triangle into a wider polygon resulting in a greater selection of colors. Figure 4 shows the triangle used by the Rec. 709 color standard used by many televisions today.

By using a multi-primary color wheel and BrilliantColor™ technology, we are able to expand the color gamut to that defined by the outer polygon (dotted line).

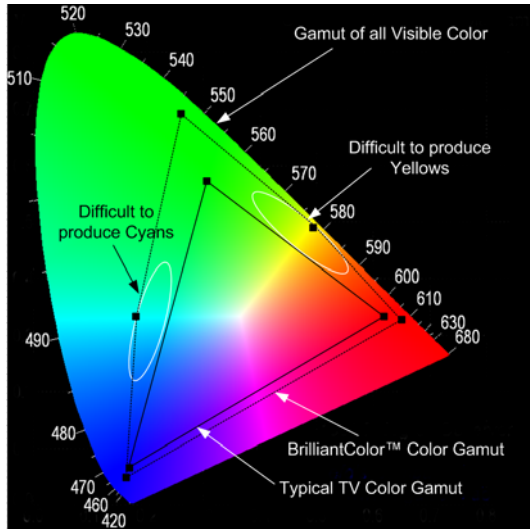


Figure 4 – BrilliantColor™ Color Gamut

This new color gamut represents colors in nature better than the three color gamut typically used in today’s display systems. The new gamut affords better balanced chrominance and luminance for life-like colors giving the viewer the ultimate visual experience.

Improved Color Gamut using just RGB Color Wheels

Color processing improvements may also be realized when BrilliantColor™ technology is applied to traditional red, green, blue (RGB) color wheels. All color wheels have a transition region between the different color filters. During the period of time that this region illuminates the DMD, the color processor is uncertain what color of light is actually on the DMD. For example, when the red/green spoke illuminates the DMD, the DMD sees a combination of red and green light.

Color processing can take advantage of this situation. Combining red with green yields yellow light. Similarly, combining red with blue yields magenta while combining blue with green yields cyan

(reference Figure 5). In this case, the yellow, magenta, and cyan color points lie within the gamut triangle defined by the red, green, and blue filter color points (since this color is created by combining two colors within the gamut). This is slightly different from a multi-primary color wheel system which adds new color points outside of the triangle.

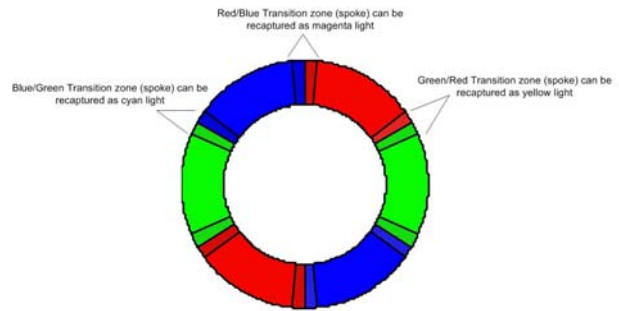


Figure 5 -- RGB Color Wheel and Spokes

BrilliantColor™ technology can be configured to process the spoke regions as a secondary color (e.g. the green/red spoke would be processed as yellow). The color processor is able to use the yellow, cyan, and magenta light to improve the brightness of the display which allows the use of more saturated primaries (reference Figure 6).

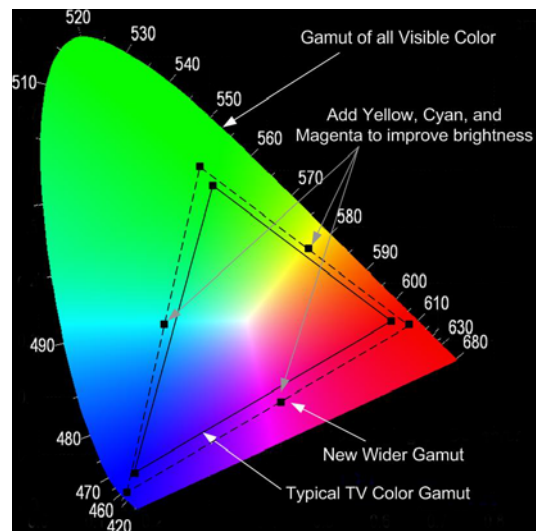


Figure 6 - Brighter Color Gamut from RGB Color Wheel

Additional Benefits of BrilliantColor™ Technology

In addition to gaining improved efficiencies in the illumination optics and providing a wider color gamut, BrilliantColor™ technology offers additional improvements to the rendering of images on DLP® displays.

The BrilliantColor™ algorithms are implemented using floating point arithmetic. Unlike traditional color algorithms which are implemented using a fixed number of bits, the BrilliantColor™ algorithms use a floating point algorithm which results in greater computational accuracy. This results in less noise and more accurate colors at the display. Combining the improved computational accuracy with the extended color gamut, DLP® projection systems utilizing BrilliantColor™ technology are capable of generating over 200 trillion color shades.

Furthermore, BrilliantColor™ technology is extremely flexible, allowing the OEM to completely customize the display color to their specification allowing for differentiation in the market place.

Conclusions

BrilliantColor™ technology was designed to improve the optical efficiency of DLP® display engines. For UHP lamps, this technology is able to achieve up to 50% improvement in brightness over traditional three color solutions. The utilization of up to six colors enables the use of a wider color gamut. The wider color gamut is better suited to accurately display colors found in nature than three color solutions, giving the viewer a truly life-like image.

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