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White Paper

Are You Ready For Deep Color?
-Introducing the PACSmate GrayEasy® Technology

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1. Preface

In recent years, more and more color images have been introduced to the medical environment. Some new applications, such as three-dimensional software, nuclear medicine, CAD programs, and color ultrasound drive the demand for color displays. A display system, which is able to display more than 8-bit color depth, is demanded by medical imaging industry because most of the raw images from medical modalities are usually 12-bit to 16-bit. “Deep Color”, a new color technology, supports 30-bit, 36-bit and even 48-bit color depth, enabling more subtle and precise diagnostic images from the modalities, such as CR, CT and MRI. With the introduction of Deep-Color, the medical imaging industry now has a much easier way to break the 8-bit barrier of traditional digital display systems.

This white paper will first explain what deep color is and why deep color is important for medical imaging applications. It will also introduce PACSmate GrayEasy® technology, the easier way to drive the display result to 30-bit for color images and 12-bit for grayscale images with deep color and HDMI™ 1.3 color compliance.

Figure 1 High definition color image supported by deep color

2. Deep Color Introduction

2.1 What is deep color?

In a traditional digital display system, most of the color measurement is based on the sRGB color space, shown in figure 2, according to international standard- IEC 61966-2-1. Traditional display system usually only allows 60~80% of all available colors in the nature to be displayed with maximum 16.7 million colors (24-bit) distinguishable by human eye. Thus, terms like “High-Color” and “True-Color” are referred to the color-depth of the traditional display system.

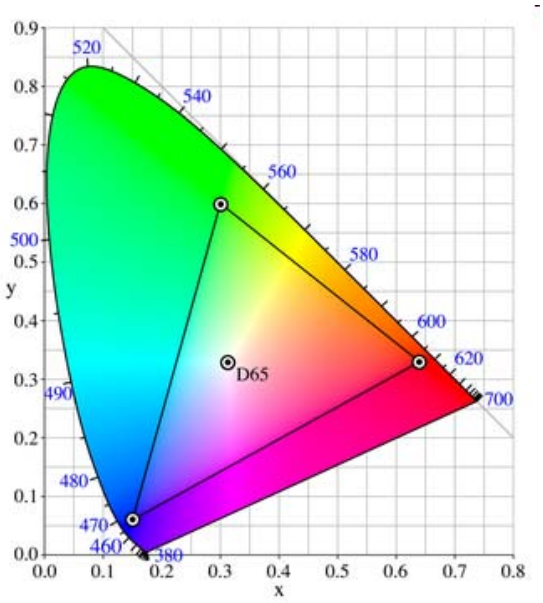

Figure 2 sRGB color space

In a high-color (also called “thousands of colors”) digital display system, colors are defined by 5-bit for each RGB component plus one more bit for green component since human eyes are more sensitive to green colors. Thus, in figure 3, only 16 bits are used to describe total 65.5 thousands (2^{16}) of color in a high-color display system.

Bit	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
Data	G	R	R	R	R	R	G	G	G	G	G	B	B	B	B	B
	2	2^5= 32 colors					2^5= 32 colors					2^5= 32 colors				

Figure 3 Color description in a high-color display system

In a true-color (also called “millions of colors”) digital display system, colors are defined by 8-bit for each RGB component. Thus, in figure 4, 24 bits are used to describe total 16.7 millions (2^{24}) of color and only 8 bits are used to describe total 256 shades of gray in a true-color display system.

Figure 4 Color and grayscale presentation in a true-color display system

“Deep-Color” (also called “billions of colors”) defines more than 24 bits color depth in a digital display system. In figure 5, total 1.07 billions of colors are reached in a deep-color display system. Based on international standard- IEC 61966-2-4 published in January 2006, deep color is referred to xvYCC color space which has 1.8 times as many colors as the sRGB color space. Deep color usually has a low lightness and a high saturation degree plus intense color with no appearnace of black. Deep Color gets rid of the on-screen color banding which degrades the clarity of images. Tonal transitions in deep color are smooth and graduations in deep color are very subtle. Deep color increases contrast ratio, and represents many times more shades of gray between black and white. With a deep-color display system and a xvYCC color compliant display unit, the medical imaging applications are able to display more grayscale images which is 10-bit, 12-bit or even higher. The enormous amount of colors plus more shades of gray enables the clearest images, increasing the display accuracy for diagnostic applications.

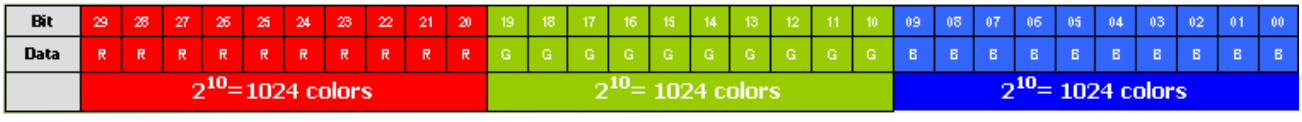

Figure 5 Color presentation in a deep-color display system

2.2 What is a “deep color device”?

A deep-color device is defined as a device, which is capable of directly displaying colors in a specific format without having to minimize the number of colors by software. The most popular data transmission technology to support deep-color is the Transition Minimized Differential Signaling (T.M.D.S.) protocol used by DVI and HDMI™ video interfaces. Unlike a traditional display device, a deep color device is able to decrease unwanted posterization occurred due to the insufficiency to accurately demo the continum of color gradation. A deep color device can display more subtle color images with higher color depth support, giving a vividness and color accuracy when viewed by human eyes.

2.3 What does a deep-color display system consist of?

There are three important elements in a display system to decide the capability of supporting deep-color, including deep-color compliant software, the HDMI™ 1.3 compatible graphic controller and the deep-color compliant monitor display unit.

Deep-color compliant software usually includes the operating system and the image viewing application. In figure 6, take the leading Microsoft® operating systems as examples, only the Windows® Vista™ supports 30-bit, 36-bit, and 48-bit in the color management system. Together with an image viewing application software designed based on Windows® color system v1.0, the software element is able to support deep-color.

Operating system	Color management System	Color depth
Windows® 95	Image color management (ICM) v1.0	24-bit
Windows® 98 Windows® 2000 Windows® XP	Image color management (ICM) v2.0	24-bit
Windows® Vista™	Windows® color system (WCS) v1.0	30/36/48-bit

Figure 6 Color management systems under various operating systems

In the HDMI™ revision 1.3 published in June 2006, the maximum TMDS bandwidth was increased to 10.2 GB/sec and was added the support for xvYCC color space and for deep-color with maximum 48-bit color depth. Thus, a graphic controller which is compatible with HDMI™ 1.3 specifications is capable of supporting deep-color.

For a deep-color compliant display unit, the pixel data receiver hardware in a display unit must be able to process HDMI™ 1.3 signaling and must have sufficient look up table (LUT) to process pixel data higher than 8-bit per RGB component.

3. True 30-bitDeep Color Ready By PACSmate GrayEasy® Technology

Deep color expands the color depth from millions to billions, showing more subtle color images on a display unit. In this chapter, we will introduce the innovative GrayEasy® technology, which realizes the true 30-bit deep color images supported by HDMI™ 1.3 specifications.

The innovative GrayEasy® technology

The innovative GrayEasy® technology integrated in PACSmate® monitors drives color image through built-in display controller instead of conventional software. The GrayEasy® technology enables more than 30-bit display capabilities without replacing the monitors for future HDMI™ 1.3 deep color format. Through complete 12-bit grayscale and 30-bit deep color image data flow, illustrated in figure 7, the PACSmate® monitors display true 30-bit color images without any color banding effect and support future upgrade to a deep color system without additional cost. The GrayEasy® technology can further create more shades of gray through built-in color-to-grayscale converter which reproduces color brightness into grayscale, enabling 10-bit or 12-bit pixel grayscale images displayed on the PACSmate® monitors. The built-in hardware Look-Up-Table (LUT) in the GrayEasy® display system for DICOM calibration further ensures the image quality for the use in diagnostic environments.

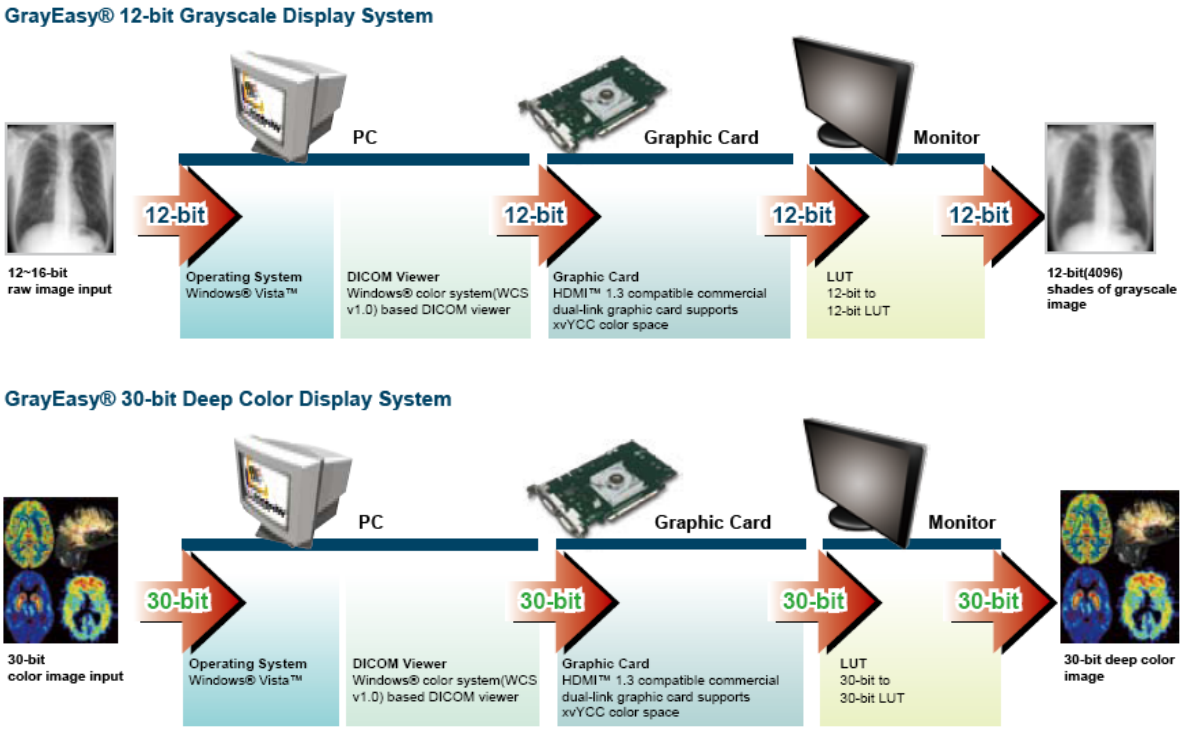

Figure 7 The image data flow driven by IEI GrayEasy® technology

4. Summary

With the growing number of color images introduced to the medical applications, the technology to display higher color depth of images is important in the medical imaging industry. In this paper, the deep color, a new format of color images is introduced. Unlike the traditional digital display system that at most 16.7 million colors (24-bit) can be displayed, the new deep color display system can present more than 30-bit color images based on the new xvYCC color space. To display the clarity of deep color image, a deep-color device is introduced and is defined as a device which is capable of directly displaying colors in a specific format without having to minimize the number of colors by software. For a display system, there are three important elements to decide the capability of supporting deep-color, including deep-color compliant software, the HDMI™ 1.3 compatible graphic controller and the deep-color compliant monitor display unit. With these required elements, a display system can present the most precise images supported by future HDMI™ 1.3 specifications.

To support deep color images, the innovative GrayEasy® technology integrated in PACSmate® monitors is proposed in this paper as well. The GrayEasy® technology drives color image through built-in display controller instead of conventional software, enabling more than 30-bit display capabilities without replacing the monitors. To upgrade to future HDMI™ 1.3 specifications without additional cost, GrayEasy® display system fully supports deep color from HDMI™ compatible commercial dual-link graphic controller, HDMI 1.3 operating systems to HDMI 1.3 deep-color format in the PACSmate® display unit. The GrayEasy® technology can further create more shades of grayscale images through built-in color-to-grayscale converter, enabling more subtle and precise grayscale images displayed on the monitors.