Digital Color Workflows and the HP DreamColor LP2480zx Display

HP DreamColor

Introduction

Color is all around us. And it's often important (you look healthy!; is this stove hot?). While not life-threatening, color is also a very important part of many of today's digital workflows—in product design, entertainment, broadcasting, and advertising. Further, as the quality and economics of tools for desktop publishing improve, the use of color is increasingly commonplace in consumer digital workflows, from printing photographs to creating brochures for small businesses.

However, maintaining color predictability across a workflow, which necessarily employs multiple devices and media (e.g., digital cameras, scanners, workstation displays, printers, cinema and video), is so difficult that it often becomes an afterthought—or is ignored altogether. Artists and designers need to know that the colors they see at their display will accurately be reflected in their end product, whether it's an animated film, a product (or its packaging), a video, or a printed advertisement.

In early 2007, Hewlett-Packard introduced HP DreamColor—a set of technologies and use models that provide accuracy, predictability, and ease of use for color reproduction systems. HP DreamColor combines HP technologies with existing color management tools to provide outstanding color reproduction throughout a digital workflow. Importantly, HP DreamColor technologies remove the complexity involved in producing accurate and predicable color across a series of digital devices. Built into a series of applications and devices—displays, printers, and presses—the technologies streamline the process, allowing graphic arts professionals to focus on results instead of process.

This paper provides a brief overview of working with a digital color workflow, with a focus on the HP DreamColor LP2480zx Professional Display. The HP DreamColor LP2480zx display is the world's only color-critical 24-inch diagonal widescreen LCD display based on the HP DreamColor technology. It is the first affordable CRT replacement for color-critical applications that provides billion-color accuracy—from vision through production.

Managing Color

We will begin with a brief introduction to color, including a description of one method of mathematically quantifying color. Next, we will present an overview of a typical digital workflow, and finally, we will discuss how color is maintained throughout that workflow.

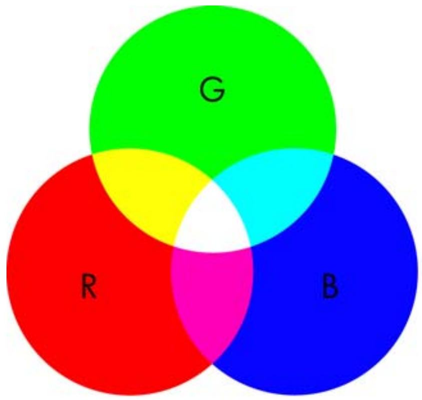
The Properties of Color

Color is a tricky thing. Nothing really *has* color; color is a perception, generated in the eye-brain system in response to given stimuli. To perceive light, our eyes use three different receptors to decode wavelengths of light into something that our brain interprets as color. The three different receptors are each sensitive to different wavelengths, roughly corresponding to the red, green, and blue portions of the color spectrum. Our eyes, then, perceive any color that we humans are capable of seeing by combining different "output values" of the red, green, and blue receptors.

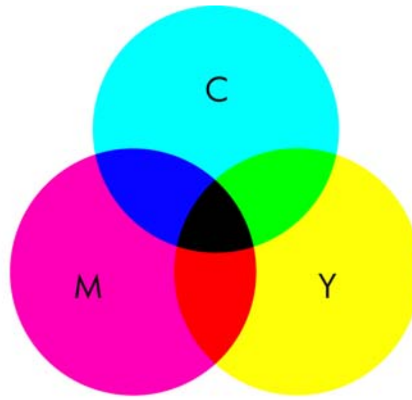
There are two different ways that the different wavelengths of light (corresponding to color) can be created: light can be emitted from a source (emissive source), or can result from the wavelengths of light that *were not* absorbed after light is reflected off of an object (reflective source). These two ways of creating can be translated into two different "sets" of color—RGB and CMYK.

The RGB Color Set

We refer to the red, green, and blue (RGB) colors created from an emissive source as *primary* colors. Specifically they are called *additive primaries*, because any color that a display device is capable of producing is made by adding different intensities of each of these three colors of light. Since our eyes are specifically sensitive to the three additive primary colors, electronic devices that generate light (e.g. color television) are generally designed to emit light in the red, blue, and green spectrums. Such devices are usually referred to as RGB devices.



RGB: The additive color model



CMY[K]: The subtractive color model

The CMYK Color Set

Objects that don't emit their own light exhibit color by virtue of the wavelengths of light that are reflected off of them. In other words, to produce a particular color, we have to *subtract* the proper primary colors (because the surface that is reflecting will absorb different amounts of the three additive primaries). For example, if blue light is the one mainly absorbed, leaving only the red and green parts of the spectrum, the perceived color is yellow (red + green). Similarly, subtracting the green light produces a reddish-purple hue (red + blue, or *magenta*), while subtracting the red results in *cyan*, a combination of blue and green.

Thus, the cyan-magenta-yellow set comprises the *subtractive* primaries—typically used in printing. However, since real-world subtractive primaries don't really absorb *all* the light at any given wavelength, combining the three doesn't generally give a very good black. So, black ink is commonly added to the C-M-Y set, resulting in "CMYK" printing. ("K" is used for black, since "B" was already taken for the blue in the RGB set).

Color Spaces

Over the years, many different ways of quantifying color have been developed. Generally, a model that represents how color is represented is known as a *color space*. Different devices and applications can (and do) use different color spaces.

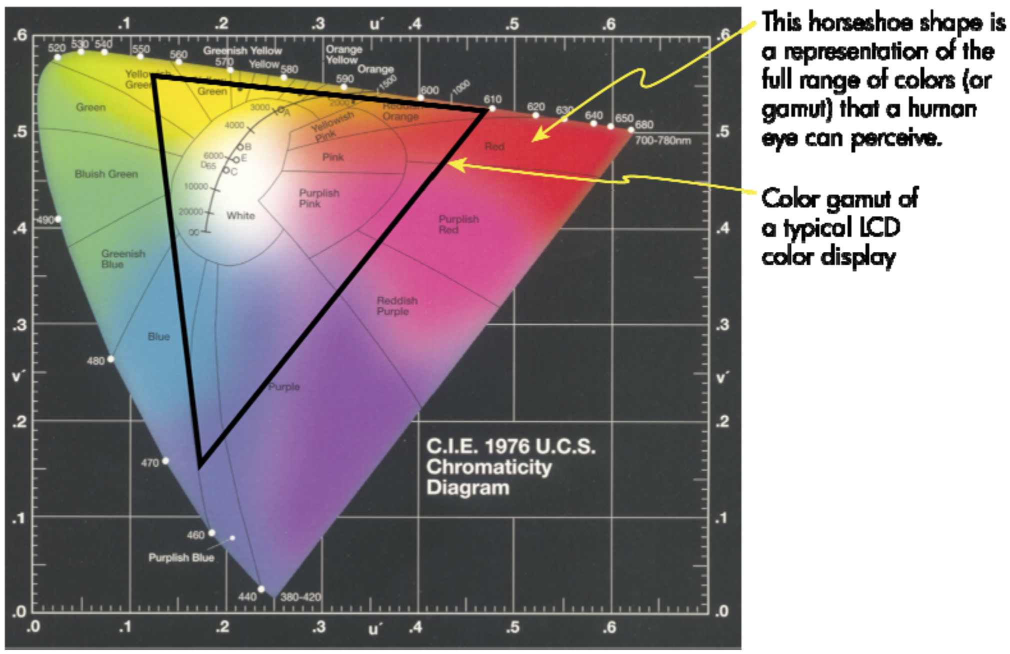
In 1931, the International Commission on Illumination (or CIE as it's known by its French initials) published a specification that described standardized curves based on the sensitivity of normal human vision vs. wavelength for the three types of receptors in the eye. These are known as the CIE 1931 color-matching functions, and they lead directly to a space defined by three standardized primaries known as *X*, *Y*, and *Z*. A simplified "two-dimensional" model was derived from the *XYZ* system, and is referred to as the CIE *xy* color space, or more correctly the *xy chromaticity coordinates* or *chromaticity diagram*.

The CIE 1931 system takes into account humans' response to different wavelengths of light, and has become a standard in the electronics industry for specifying the ability of an electronic device to reproduce color. However, the CIE 1931 chart is not a perceptually uniform color space. In other words, the same change in distance on the xy chart in two different regions generally does not mean the same change in perceived color as a human eye would see it.

In 1976, a system similar to CIE 1931 was developed that partially corrects for the non-uniformity of CIE 1931—it is called the L*u*v* color space, and has an associated u'v' color chart; the "color gamut" is discussed in the next section). The challenge (as we will explore) is mapping color spaces over a range of input devices, applications, and output devices while maintaining (or supporting) color range accuracy and predictability.

Gamuts

The CIE 1976 system is a useful way to describe the color that a certain device or system is capable of producing. Since it is based on the additive primary colors (RGB), the subset of colors that a device or system can produce can be described by a triangle superimposed on a CIE chart; such a triangle is referred to as the *gamut* of the device or system. The vertices of the triangle represent the maximum output values for each of R, G, and B that the device or system is capable of producing.

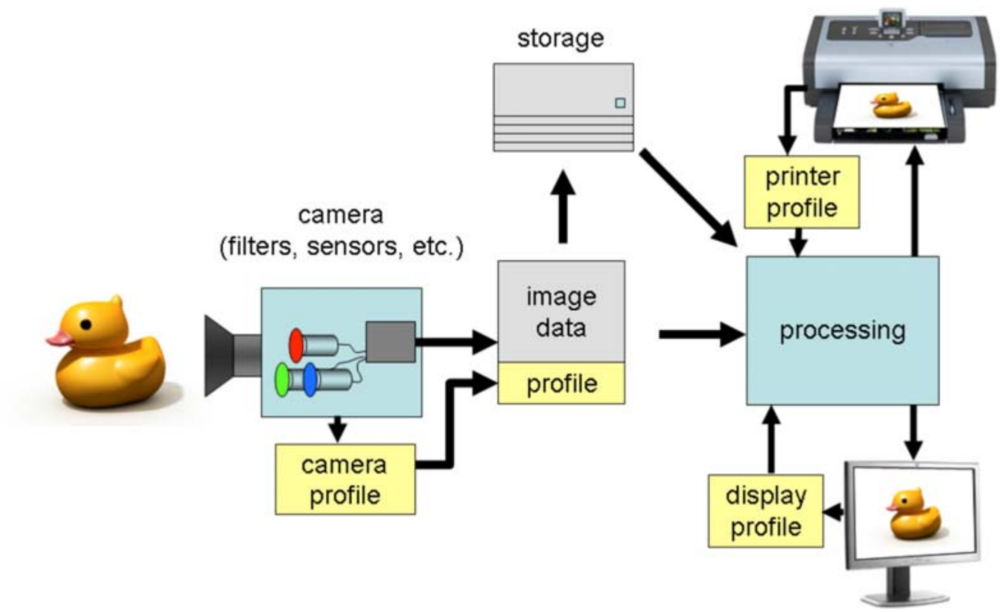


The first thing to note from the chart is that there seems to be quite a large area of color that our display or printer simply can't produce. Part of the reason for this is simply that no display or printer is technologically capable of producing these colors; and part of the reason is mathematical. There is simply no way that a triangle can cover the entire visible space without at least one of the primaries being off in the black area outside of the horseshoe-shape—which would mean the primary itself would be somewhere outside of the range of visible colors.

We will discuss the gamut of different devices later when we review the features of the HP DreamColor LP2480zx display.

The Digital Workflow

In the typical digital workflow, an image and its color are generated synthetically (e.g. animation, advertising collateral, etc.) or are input through some device (scanner, camera, etc.) and the digital information representing the image is stored in a data file (as shown in the figure below). Since different devices treat color differently, the challenge for vendors of computer and imaging equipment is to provide users with consistent color across the entire workflow.



Color profiles

In an effort to maintain predictability of color across the range of devices encountered in the workflow, each device maintains a numeric description of how it manipulates color—called a profile. Devices and applications use a profile to map color information from one device to another throughout the workflow.

The most widely adopted profile format is that created by the International Color Consortium (ICC[1]). The ICC was established in 1993 to encourage vendors to standardize on a single format, which would allow vendors to communicate profile information within a workflow.

Color accuracy and predictability

Well then, what is the problem? We have:

- A "pretty good" way of mathematically describing how a color will look on a specific device (the CIE 1931 or CIE 1976 system);
- A collection of pre-defined color spaces that describe the range of colors applicable to that space;
- An international standards body (ICC) that defines how devices and systems can communicate color information with each other; and
- Competitive pressures that encourage vendors to design devices that will depict color as accurately as possible.

The challenge is to maintain both color *accuracy* and color *predictability*. Accuracy means that a color is always the same when measured against a known reference, and generally involves some empirical form of measurement such as a colorimeter or a spectrophotometer. Predictability means

[1] See www.color.org.

that a color is absolutely reproducible, across workflows, across pages, across projects and across teams spread around the globe.

Both accuracy and predictability require a closed feedback loop. In other words, a sample of an output page on a printer (or a specific swatch on a display) must be actively measured, compared with a standard, and the results fed back to the device. This can be a cumbersome process (and almost always requires human intervention), and one that is only periodically performed on devices used in color-critical workflows.

HP DreamColor Technologies

In March 2007, HP introduced an integrated system of use models, technology, and products that provide accuracy and predictability for digital color workflows. The system, called HP DreamColor, leverages the standards described earlier in this paper, and introduces software and hardware products specifically designed for color accuracy and predictability. HP DreamColor technologies makes color management—which once required specialized equipment, highly trained personnel and multiple, complex processes—a more intuitive process with fewer steps.

Background

HP DreamColor was originally defined to meet the standards for color accuracy required by the animation industry, specifically to support HP's collaboration with DreamWorks Animation SKG™ and their creation of the *Shrek* series of animated movies. DreamWorks animators must absolutely be able to depend on accurate color reproduction, from the animator's desk to the movie theater[2] and into the home.

Specifications

At a minimum, the HP DreamColor system specifies a hierarchy of device requirements, including[3]:

- Specifications for media, ink, and toner properties with respect to color gamut, dynamic range, and stability over time, etc.
- Device repeatability—predictability in color reproduction from one operation to the next.
- Device accuracy—the degree to which in-gamut colors can be reproduced correctly.
- Cross-device predictability—the degree to which a consistent color appearance can be maintained across a wide range of display or printing technologies with widely varying gamuts.
- Reproduction quality—the degree to which the system produces pleasing reproductions that optimally utilize the capabilities of each available medium.

Initial products that employ HP DreamColor technologies are professional photo printers and digital presses, including the HP Designjet Z2100/Z3100 Photo Printer series, the HP Indigo 5000 and ws4500 presses, and the HP Photosmart Pro B9180 Photo Printer.

As an example of an implementation of HP DreamColor technologies, the HP Designjet Z2100/Z3100 Photo Printer includes a spectrophotometer for printer calibration that delivers print-to-print and printer-to-printer color predictability. The spectrophotometer can be used to automatically generate ICC profiles that adapt the printer to different media and print workflows.

Of course, the latest product from HP that utilizes HP DreamColor technologies is the HP DreamColor LP2480zx Professional Display.

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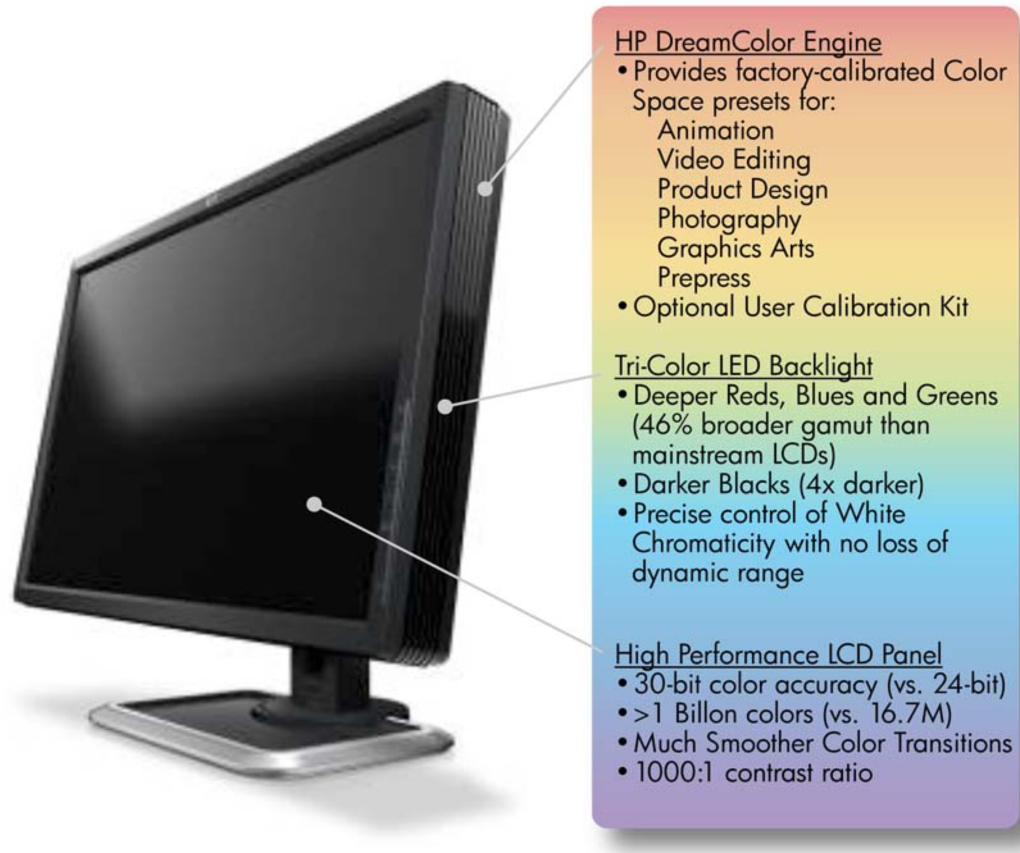
[2] For more information on HP DreamColor and *Shrek*, see http://h30267.www3.hp.com/country/us/en/features/dreamcolor/index.html.

[3] "HP DreamColor Summary," Dr. Johan M. Lammens, Senior Color Scientist, HP Large Format Printer Group, October 2007.

The HP DreamColor LP2480zx Professional Display



The HP DreamColor LP2480zx display is the next step for professionals that work in a color-critical environment (**Error! Reference source not found.**). The display combines 30-bit color (over one billion color possibilities) with unprecedented color control to provide end-to-end color predictability in a digital color workflow.

Features

The display is a 24-inch diagonal widescreen (1920 x 1200 resolution) Liquid Crystal Display (LCD) with HP Tri-color LED Backlight. The LCD panel has 30-bit color accuracy (10-bits per color channel), which provides a total of over 1 billion color combinations. With 30-bit color, the number of colors is greatly increased, reducing banding artifacts that can be present in today's 24-bit displays.

The RGB LED backlight provides an extremely wide color gamut, and ensures stable control of white point and luminance. The HP DreamColor Engine provides accurate color management and color space remapping. The Engine supports multiple color space emulation presets, including full gamut, Rec. 709, sRGB, Rec. 601, Adobe RGB and DCI-P3 emulation (97%), as well as user-defined color space. The emulation of these spaces without loss of 8-bit dynamic range is achieved through a combination of color space remapping by the HP DreamColor Engine; 10-bit drivers on the LCD panel; and white point control via the LED backlight unit.

All of the HP DreamColor LP2480zx display parameters can be adjusted via standard display-control interfaces (USB & DDC/CI interfaces and MCCS command-set), enabling the use of standard or custom color calibration software.

An optional HP DreamColor Advanced Profiling Solution kit is available for calibrating and profiling the HP DreamColor LP2480zx display, and for validating and optimizing ICC profiles. The kit contains a colorimeter and related software (for both Microsoft® Windows® and Apple Mac OS X; Linux support is planned through an open source project) that provides a number of options for display calibration (white point, gamma, and luminance). The APS will also validate the viewing environment ambient lighting conditions. The HP APS can be used with the HP Designjet Z Photo printer series to provide an end-to-end calibrated ICC color workflow[4].

The following table provides a summary of the features of the HP DreamColor LP2480zx and compares these features to other current display technologies.

	Customer Criteria For a CRT-replacement color-critical display	**High-End CRTs** (Not produced since 2005)	**Mainstream LCDs**	**Current Color-Critical LCDs**	**HP LP2480zx Display**
Black Level	Black is dark enough for low light scenes.	✓Black is dark enough	×Typical 0.5 cd/m²	×Typical 0.5 cd/m²	✓0.05 cd/m² black level at 50 cd/m² white
Color Gamut (% NTSC CIE 1976)	Covers sRGB, SMPTE-C, Rec. 709 & Adobe RGB and DCI-P3 emulation with color space management.	×81%, no color space conversion	×81-118%, no color space conversion	✓81-118%, some with color space conversion	✓134%, color space management via HP DreamColor Engine
Color Resolution	More bits per color minimizes banding artifacts.	✓Better, less banding	×24-bit LCD panel ☛16.7M colors	×24-bit LCD panel ☛16.7M colors	✓30-bit LCD Panel ☛>1 Billion colors
Gamma Correction	Accurate, adjustable tone response or "gamma".	✓Native Gamma of CRTs is very good	×Non-ideal Gamma and not adjustable	✓Some w/ programmable Gamma	✓Programmable Gamma + 10-bits ☛less artifacts
White Point	Adjustable without visual artifacts.	✓Adjustable in CRT with manual tuning.	×Not adjustable in display. Loss of dynamic range; introduces banding artifacts.	×Most have no white point control in backlight. Loss of dynamic range; introduces banding artifacts.	✓Adjustable in display via RGB LED Backlight with no loss of dynamic range.
Color Calibration	Adjust gamut, gamma, white point in display without artifacts.	✓Only white point is adjustable.	×None are adjustable without loss of dynamic range.	✓Some lack white point control in backlight.	✓All properties programmable in display.
Frame Rates	Display 24 fps film and 50/60 fps video without tearing artifacts.	✓Variable frame rate.	×60 Hz panel refresh rate. Other frame rates may cause artifacts.	×60 Hz panel refresh rate. Other frame rates may cause artifacts.	✓Panel rates 47.0-51.0 & 58.72-61.46 Hz. No tearing.

Platforms

The HP DreamColor LP2480zx display is best suited for HP Personal Workstations, as they have the processing power and expansion capabilities to support the display's feature set. HP workstations will offer professional graphics cards with 30-bit color support that are certified on the applications that are needed for color-critical workflow, whereas on-workstation platforms may not offer 10-bit professional graphics card support nor have ISV certifications (or both). In addition, applications that are able to take advantage of the color-critical display—animation, film and video, broadcast, product design and graphic arts—generally need large physical memory, a robust I/O subsystem, and multiple processors. Because of these features, HP Personal Workstations are ideally suited for such applications.

[4] See www.hp.com/go/graphicarts.

Conclusions

The HP DreamColor LP2480zx Professional Display combines the latest display technology with HP DreamColor color management processes and use models to provide users industry-leading color-critical performance at an affordable price. Artists and designers in animation, film and video, broadcast, product design, and graphic arts industries can replace their outdated CRTs with an affordable, color-critical, and energy-efficient display that exceeds CRT performance standards.

The display is complemented and supported by HP's broad range of powerful personal workstations. Artists, content creators and designers in color-critical industries can count on the performance, expandability, and robustness designed into the personal workstation products. Users in color-critical environments are encouraged to examine the benefits of the HP DreamColor LP2480zx Professional Display, HP Personal Workstations, and HP DreamColor technologies.

For more information

http://www.hp.com/go/displays
HP displays

http://h30267.www3.hp.com/country/us/en/dreamcolor

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