

Controlling Wide-Gamut Displays

Portrait Displays, Inc.

Wide-Gamut Displays and Color Accuracy

A computer display's gamut is the amount of colors the display is capable of reproducing. The sRGB color space is the current gamut standard for computer displays. This standard was developed by Microsoft and HP in 1996. The colors chosen for sRGB were those that could be reproduced by CRT (cathode ray tube) displays.

Most of the displays on the market today cannot accurately achieve all of the colors in the sRGB color space. Color accuracy can best be determined using devices such as colorimeters, spectrometers, and radio-spectrometers. The simple observation of a display without the aid of scientific measuring equipment is not an appropriate method for determining the color accuracy of that display.

Color accuracy has become paramount with the introduction of wide-gamut displays. Wide gamut is a term used to categorized displays capable of reproducing colors beyond the sRGB color space. Wide-gamut displays can be manufactured using current LCD technology with LED backlights (white or RGB). Display and computer manufacturers want displays with a wider gamut because they are much more appealing to the consumer's eyes—more colors look better.

Wide-gamut displays have a backward compatibility problem with previous color space standards. This problem is apparent when photos, movies, or images created for a narrower gamut display are viewed on a wide-gamut display. For example, if the colors in a family photo look over saturated and all the family members appear to be sunburned, the viewer will know something is wrong. Suspecting that the display is malfunctioning, the display is returned. In fact, the fault lies with the uncontrolled state of the display's extended gamut. The

solution is for the wide-gamut display to provide different color space settings appropriate for the content being viewed.

Chroma Tune provides backward compatibility to industry standard color spaces for wide-gamut displays. The majority of consumers are not aware of the technical issues of color. They want the benefits of wide gamut but are not tolerant of inaccurate color representation. Chroma Tune allows consumers to display photos accurately, the way they were originally intended to be viewed. With Chroma Tune, digital video, TV shows, DVD, Blu-Ray, web sites, e-commerce will all be displayed as the designer or content creator intended.

sRGB, Adobe RGB, Gamut, and Wide Gamut

Before describing how Chroma Tune works, a brief description of the terms used in this document are important. Color science is complicated and full of obtuse concepts and nomenclature that is difficult to understand. These ideas will be simplified in order to explain the color issues and the solutions without getting into some of the deeper details of color science.

Although a color gamut, or simply gamut, can be described as the amount of color a particular display can reproduce, the amount does not mean a specific number of colors. Color modeling is the most effective method to explain a gamut. By modeling a certain display's color reproduction capabilities, a viewable shape can be plotted. Color space is the boundary or rules used to model a gamut. For example, modeling a display's gamut in L*A*B color space means using Luminance (L), and A and B color references (defined and known color values), to mathematically model and view a gamut. Using color space rules for modeling helps when trying to compare two or more gamuts. RGB and CYMK are other common color spaces.

The three primary colors of a display are red, green, and blue. Because light emanates from a display, the display's color is said to be additive. Adding equal amounts of all three colors produces the display's lightest color, white. When the least amount of each primary color is used, the darkest color the display can achieve is produced, black.

A display's gamut can be plotted according to the color relationships that form a three-dimensional shape. Modeling a gamut using a 3D shape to represent L*A*B space shows the boundaries of a display's maximum color capabilities. The 3D shape illustrates all colors possible for reproduction by the display: saturated, faded, or gray. Colors outside the 3D shape cannot be reproduced. Only colors located and encompassed inside the 3D shape can be reproduced on the display.

Figure 1 uses L*A*B color space to illustrate the size in volume of a particular wide-gamut display. The most saturated colors reproducible by the display are located at the far edges. The

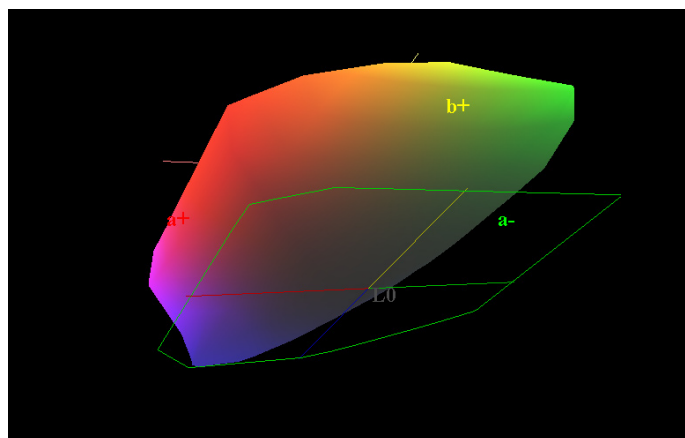
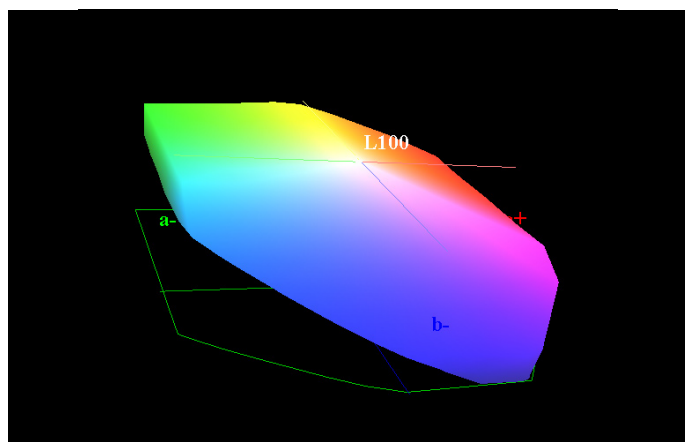


Figure 1. Gamut of a particular wide-gamut display shown in L*A*B color space. View from the top (upper image) and bottom (lower image). The vertical axis through the center represents white (Luminance 100) to black (Luminance 0).

far top represents the whitest white and the lowest bottom represents the darkest black reproducible. The most-faded colors with no tint are located at the center vertical axis connecting the top and bottom.

Using L*A*B color space modeling, standard color spaces such as sRGB and Adobe RGB can be mathematically explained. By plotting different shape structures in the same space, the differences between color spaces can be illustrated.

The color reproduction capabilities shown in Figure 1 are unique to that particular wide-gamut display. It does not imply any set standard color specifications. Different wide-gamut displays can have very different 3D shapes. The same image or photo viewed on two different wide-gamut displays can have very different colors.

Because sRGB is a defined color space, two sRGB displays should have the same 3D color shapes. The sRGB color space was mathematically defined to match the color capabilities of CRT displays. The Adobe RGB color space was created to suit photographers or professionals in need of wider gamut to accommodate colors reproducible on printers. Cameras are capable of capturing images in a wider color gamut than sRGB. Both sRGB and Adobe RGB color spaces consist of standard, well-defined primary- and white-color coordinates, yielding a consistent and predictable model, thus making them appropriate references for benchmarking a display's color performance.

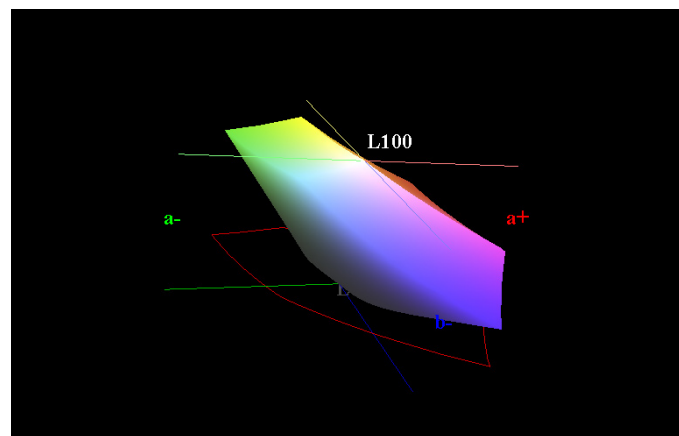


Figure 2. The sRGB color space shown in L*A*B color space.

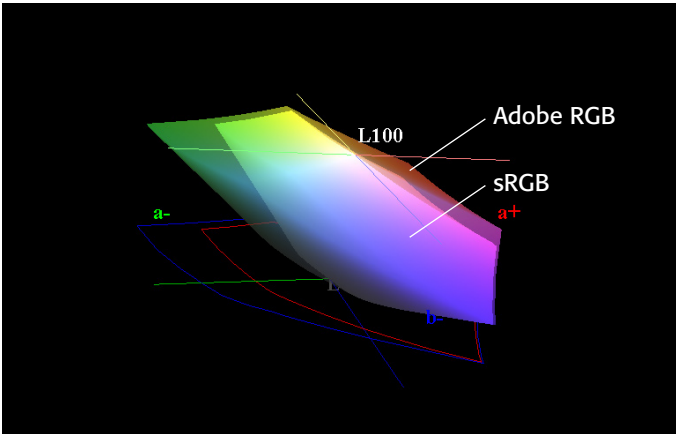


Figure 3. Comparing the sRGB color space and the Adobe RGB color space. Notice that Adobe RGB is a larger color space than sRGB. Shown in L*A*B color space.

The Problem of Exaggerated and Saturated Colors

Highly-saturated color is the simplest description of the perceived problem with wide-gamut displays. Technically speaking, the problem is inaccuracy of displaying color.

Most modern computer displays are RGB devices. They identify colors with an 8-bit-per-color system consisting of a maximum value of 255 and a minimum value of 0 for each color, in combinations of red, green, and blue. For example, a particular shade of orange can be expressed as red 239, green 174, and blue 71, or simply 239 174 71.

Computer screens are made up of thousands of tiny dots called pixels (picture elements). Each pixel is made up of three sub-elements, one red, one green, and one blue. When an

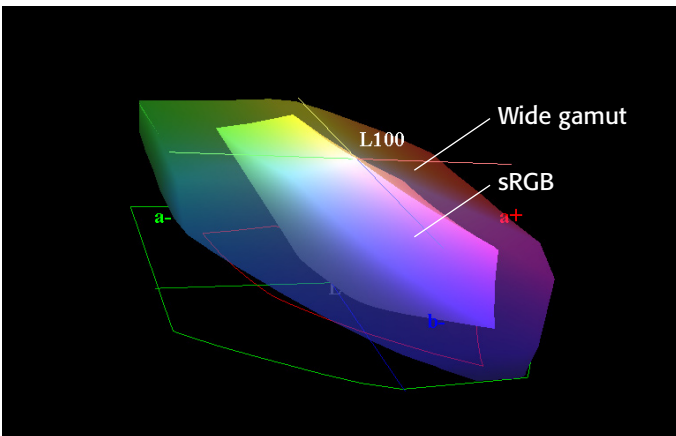


Figure 4. Comparing a wide-gamut display's color space to the sRGB color space. The 3D shape of the sRGB color space is encompassed by shape of the display's color space. Shown in L*A*B color space.

image's pixels are transmitted to the display's screen, the screen understands what colors to display by decoding these numbers into the appropriate color for each pixel. The color space used in interpreting the image's pixel values is a device-dependent color space. In an 8-bit system, a red pixel with a value of 255 sent to the display's screen will be shown as the maximum possible red the screen is capable of displaying. The maximum red can be many different colors based on the physical capabilities any particular display. If the image is encoded in sRGB, a pixel with a maximum red value of 255 is intended to be reproduced at the edge of the sRGB gamut shape (Figure 4), not the farther edge of the wide gamut display's shape. Because of this issue, a sRGB image will appear over-saturated on a wide gamut display.

Chroma Tune maps the gamut of the display to the correct color space of the content being viewed. When dealing with an image's pixel values, Chroma Tune changes the device-dependant nature of the display by creating an appropriate color space. In this manner a wide-gamut display will show a specified color space, for example, sRGB, Adobe RGB, or Rec. 709, enabling images and video to be displayed as intended. Color spaces are determined by the content, abilities, and volume of the display's gamut.

How Chroma Tune Works

Chroma tune converts the gamut of the display to a specific color space to reproduce colors as they were intended, thereby preserving the photo's, image's, or video's original intent. For example, a web site displays a photo of a new color-critical product, perhaps an article of clothing. This photo was produced using the sRGB color space. A customer visits the web site and views the product with an uncontrolled wide-gamut display. It looks good to the customer. However, because the display ignores the photo's original intended color space, it displays the product's colors using its own larger color space, resulting in the product appearing over saturated and overly vibrant. When the customer purchases the product and it arrives, it is not as expected. It will be returned, the merchant will incur unnecessary expense, and the customer will be dissatisfied with the entire experience without a clear understanding of the actual problem.



Figure 5. This image shows how an Adobe RGB image would appear on a wide-gamut display that is enabled with Chroma Tune and set to the Adobe RGB color space.



Figure 6. The same Adobe RGB image as viewed in a web page on a display with a narrow-gamut.



Figure 7. The same Adobe RGB image as viewed in a web page on a wide-gamut display without Chroma Tune.

In another example, a photographer takes colorful nature pictures with a new camera capable of capturing saturated colors using the Adobe RGB color space. The photographer reviews the photos on a Chroma Tune-enabled wide-gamut display in the Adobe RGB color space. The photos are then posted on a web site. A visitor with a narrow-gamut display will see de-saturated and dull images. The problem is that the visitor's narrow-gamut (sRGB) display clips the colors rendering them inaccurate and washed out.

Equipped with a Chroma Tune-enabled wide-gamut display, a photographer could change his display's color space to sRGB so he can be sure he is viewing his photos the same way the web site's visitors will view it. This allows the photographer to correct the content before distribution or distribute with notification of the proper information to view the content correctly.

Chroma Tune can be invoked using one of two methods. First, a user can manually choose a desired color space by selecting sRGB, Adobe RGB, or other standard color spaces in the Chroma Tune user interface. This method is useful if the user is aware of the requirements of the content being viewed.

The second method uses App Sync™ to switch color spaces automatically, according to the software application that is being used. Chroma Tune is pre-configured with a table of different color spaces that are pre-assigned to various popular software applications. Users can leave this table unchanged or simply re-assign color spaces to particular software applications. For example, if sRGB is assigned to an Internet browser

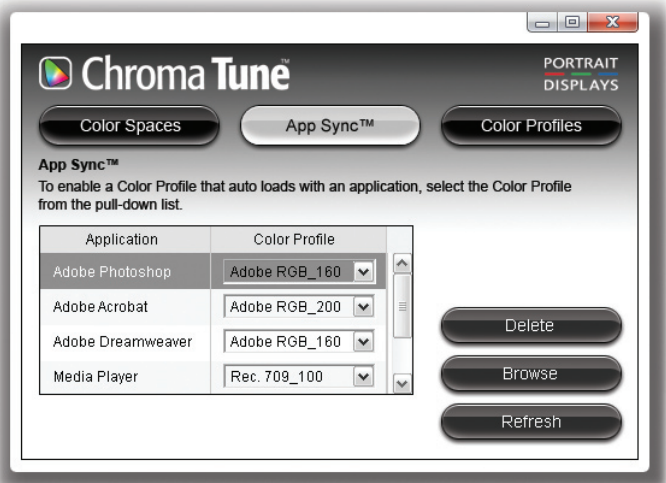


Figure 8. The Chroma Tune application, showing the App Sync panel. Users can change color space associated with a selected application.

and Rec. 709 is assigned to a media player, Chroma Tune will automatically set the display to use sRGB when the Internet browser is detected to be in use. Opening the media player to view a DVD would automatically change the setting of the display to Rec. 709.

Chroma Tune and Color Science

Chroma Tune operates in a 3D space. It moves and maps color points in 3D coordinates of X, Y, and Z. Chroma Tune achieves this by depending on a careful characterization process. In this process, an actual sample of a particular wide-gamut display is measured in a computer laboratory. A customized mathematical equation is developed just for that display. With the characterization process complete, this particular wide-gamut display can be accurately modeled with 3D coordinates that show the boundaries of its gamut. All the mathematical models and equations used in Chroma Tune adhere to the defined rules in color mathematics and science. Therefore all results on the display should be predictable and measurable. Colorimeters can be used to verify color space changes and accuracy.

Chroma Tune maps all of the color spaces that a display is capable of fully reproducing. Mathematically, if the target color space, such as sRGB, has defined coordinates (in a 3D model) located inside the display's maximum 3D shape, then the display is capable of reproducing each pixel that can be found within the sRGB's boundaries. Chroma Tune achieves this by adjusting the display's gamut, moving (or mapping) its XYZ-point locations to match the sRGB-point locations. This is done on the primary (red, green, and blue), secondary, (cyan, magenta, and yellow), and white colors. All other colors follow on the same mapping scale.

Using Chroma Tune

Chroma Tune was designed with emphasis on the everyday user. The implementation and user experience is intended to bring the accuracy of color science within the grasp of the layman while offering advanced features for expert users. Photographers and designers can incorporate Chroma Tune into their workflow. Chroma Tune produces standard ICC profiles to aid the color-knowledgeable users so they can make use of it as needed. Chroma Tune is not a replacement of any color management system or an alternative to the way

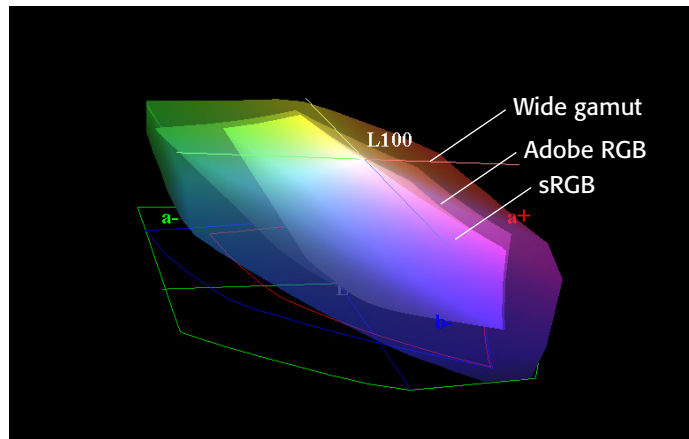


Figure 8. For this particular wide-gamut display, both the Adobe RGB and sRGB color spaces are encompassed within the display's gamut. Therefore, Chroma Tune can control the color spaces on this display to Adobe RGB, sRGB, and its full (or native) color space.

ICC profiles are used on a computer system. Chroma Tune is similar to ICC by physically changing the display.

Chroma Tune has zero impact on the system performance as it is a hardware solution, with no overhead to the system software. It utilizes available hardware by re-programming the Graphics Processor (GPU).

Chroma Tune Accuracy

The accuracy of Chroma Tune is dependent on the available colors of the display's screen, the performance of the mapping task, and the color reproduction capabilities of the display. 100% accuracy occurs when a display's gamut can totally encompass a target color space. If the physical gamut of the wide-gamut display is limited, it can prohibit a particular color space from being fully encompassed. In this case, the mapping of that color space cannot be accurately achieved and the physical gamut of the display cannot be altered, so that color space must be abandoned for this particular display.

Chroma Tune's technology is based on the characterization process where a sample display is measured to represent the full production run of a particular wide-gamut display. If the actual production run is an exact match of the sample, accuracy of 100% is achieved. Deviations in specifications and defined acceptable errors in manufacturing process will affect Chroma Tune's accuracy. Well-defined quality control and procurement procedures will result in greater accuracy and consistency of Chroma Tune.