ChromaPure Video Calibration Software

ChromaPure 3

User Manual

May, 2019

Chapter 1: Introduction: The Basics

What's Inside?

Use ChromaPure software to calibrate your flat panel or projector to industry standards. For technical support for issues not covered in this document, contact support@chromapure.com.

What to Expect from Calibration

Calibration can make either a very large or very small difference to the quality of the image on your display. Which result you get depends on several variables.

- How far from industry standards is your display out of the box? If it is properly setup at the factory (it almost never is), then calibration will make little difference. Otherwise, it can make a profound difference.
- How much control does the display offer? This varies wildly among displays. Some are better candidates for calibration than others simply because they offer a wealth of calibration controls. At a minimum a display should offer custom white balance controls in addition to the standard Contrast, Brightness, Color, Tint, and Sharpness adjustments found on all displays. The best candidates also offer adjustments for gamma, color decoding, and/or color management.
- What is the quality of the calibration equipment (hardware and software). Even those displays that are the best candidates for calibration will see little improvement if the calibrator uses sub-standard equipment.
- Finally, there is a purely subjective element to this. How sensitive are you to changes in color and luminance? The best candidates for calibration are those who have a good eye for accurate reproduction. If you are not sensitive to this, then may not notice much of a difference regard-less of the changes made.

What Do I Need?

In addition to ChromaPure software and a PC or laptop, you will need

- A color analyzer to read the light and color that your display produces.
- Some way to get test patterns into your display. The most common method is with a calibration DVD or Blu-ray disc. There are many options to choose from, including a disc that ChromaPure offers. If you have an HDMI output on your PC, then you can also use test

patterns built-in to ChromaPure. Finally, you can use an external test signal genera-tor. ChromaPure supports several.

- If you have a front projector, an illuminance meter is a good idea. The AEMC CA813 is a good, reasonably priced illuminance meter.
- A camera tripod on which to mount your meter.

Calibration Procedures

Essential Equipment

- **Color analyzer.** This is a USB or serial device that you point at the display so it can read the color and light output of the display and then connect to a computer. The best color analyzer for most people is the X-Rite i1 Display Pro. ChromaPure supports both the retail and OEM versions of this meter. We also offer a special calibrated version of either called the Display 3 PRO that offers enhanced accuracy over the stock meter.
- **Calibration Software.** You need ChromaPure to interpret the data that the meter provides, analyze the data, and plot the results on easy-to-read charts/graphs.
- **Video Test Patterns.** Finally, you'll need some way to get a test pattern on the screen. The easiest way to do this is with ChromaPure's built-in test patterns that connect to your television via the HDMI output on your PC or a DVD or Blu-ray.

  The built-in test patterns offer a an automated method for generating test patterns. For more information about this option, refer to Selecting and Configuring a Test Pattern Source, p. 19. You can also use an external test pattern generator, such as the DVDO TPG, Lumagen Radiance, or AccuPel. For more information about this option, refer to external signal generators. Either of these is an appealing option, because ChromaPure generates the needed test patterns automatically. The user doesn't have to worry about selecting the correct pattern before taking a reading because the software does that for you. ChromaPure supports several of these devices.

Once you have the items in this list, you are ready to calibrate your display.

Basic Principles

Display performance is measured in several ways:

White and black levels. The most basic aspect of video calibration is getting the correct white and black levels. White level—the intensity of light the display produces when the video signal is 100%—is adjusted by the contrast control. Black level—the intensity of light the display produces when the video signal is 0%—is adjusted by the brightness control. For more information on setting white and black levels, refer to Setting White and Black Level, p. 35.

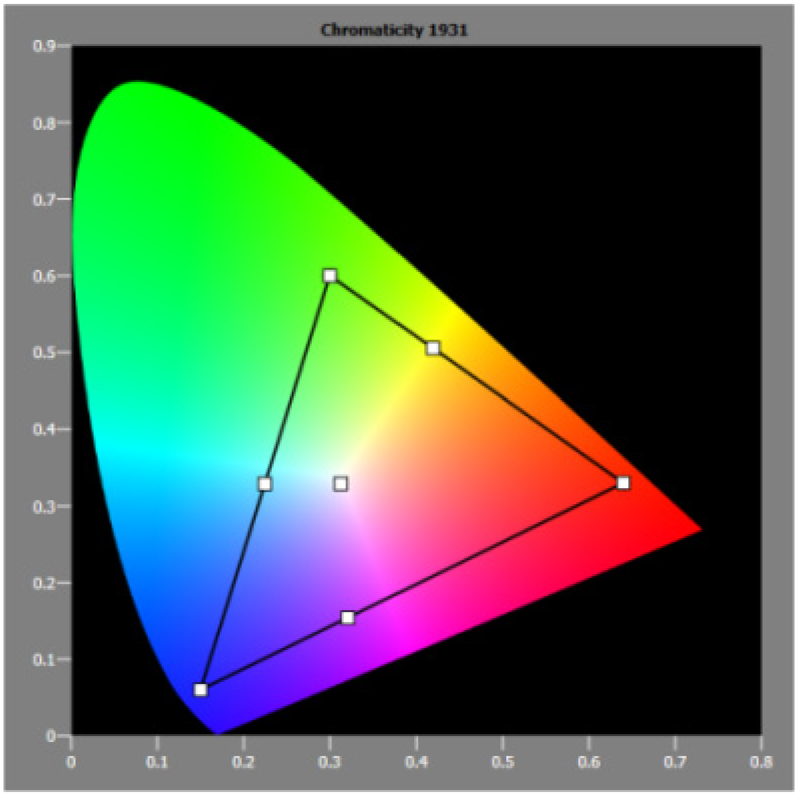
Sharpness. This adjustment is a holdover from the days of analog video and generally should be turned down considerably or simply left at its default setting. On many modern digital displays, the sharpness control has very little effect on the image.

White Balance. This aspect of color performance is arguably the most important. It concerns the display's ability to render a neutral shade of white. The color of white from darkest gray to the brightest white is called the grayscale. If the display can't reproduce a neutral white, then it will add an unnatural color cast to all images. For this reason, it is absolutely essential to correctly calibrate the display's white balance. For more information on calibrating white balance, refer to Setting White Balance, p. 36.

Color Decoding. This term refers to a process that is used to lower bandwidth requirements by encoding the native RGB signal into YCbCr, which must then be decoded back to RGB prior to display. There are different encoding/decoding standards, so sometimes a poor design in the television or disc player may lead to color decoding errors. These errors are primarily seen as primary colors (red, green, or blue) with incorrect luminance and/or secondary colors (yellow, cyan, or magenta) with incorrect hues. All commercial displays include a Color and Tint control. These are designed to resolve color decoding errors, though their effectiveness is extremely limited because Color adjusts the luminance of ALL of the colors and Tint effects hue of ALL of the secondary colors. The problem is that typically displays have color decoding errors that effect the colors differently. For example, you could adjust Color/Tint to get the correct luminance of blue and the correct hue of cyan, but the luminance of green and the hue of yellow may still be inaccurate. You could adjust the color control to get red right, but then blue and green could be inaccurate. See the problem? A full set of color decoding controls addresses this problem by offering color/tint controls that operate on red/magenta and green/yellow independently. Then you can use the main Color/Tint controls to adjust blue/cyan. For more information on resolving color decoding errors, refer to Correcting Color Decoder Errors (Color and Tint), p. 41.

With most modern digital displays color decoding is no longer an issue. Furthermore, if the display has a properly functioning color management system (CMS), the Color/Tint controls should rarely be used.

Color Gamut. This is the range of colors that the display is capable of rendering. The gamut is most often represented as a triangular pattern plotted on a standard tongue-shaped chart as shown below.



The gamut is defined by the xy coordinates of the primary colors (red, green, and blue) and the white point. The secondary colors (cyan, magenta, and yellow) are derived from them. These color points have specific definitions for both standard and high definition signals. All commercially available video material is mastered according to these standards. If the display cannot reproduce the gamut accurately, then the image will visibly suffer. Digital displays used to offer especially poor performance in this regard, but recently they have gotten much better. The only way to fix errors in the gamut is with a Color Management System (CMS). A CMS can make a profound difference to the performance of the display, but few offer one and of those that do not all work properly. For more information on using a CMS with ChromaPure, refer to Using Color Management, p. 38.

Gamma. This performance parameter describes how the display responds to increasingly intense signals. As a signal gets more intense, if the display rises out of black very fast, then it has a high gamma. If it rises out of black slowly, then it has a low gamma. The optimal gamma is expressed numerically. Aim for a gamma in the 2.2-2.35 range. For more information on adjusting gamma in ChromaPure, refer to Measuring and Adjusting Gamma, p. 42.

It is important to understand two things about these aspects of display performance.

First, these are independent aspects of image quality. You can have good grayscale tracking and poor color decoding. You can have good color decoding and a very inaccurate color gamut. The bottom line is that each needs to be adjusted separately.

Second, adjusting them is a reiterative process. Although these aspects of image performance are independent, adjusting one often has an effect on another. This means that after you finish adjusting one area of performance, it is a good idea to go back and look at areas you have already worked on to see how adjustments in one area may have affected other areas of performance. Generating a calibration report is a useful tool for checking this. For more information on generating a calibration report, refer to Running a Calibration Report, p. 51.

Essential Terminology

xyY. This is a common method for precisely measuring color performance. x and y are coordinates on the triangular CIE chromaticity chart shown above that plot colors on a graph relative to their reference points. Y represents the luminance of a color, a third axis of color which is not plotted by on the two-dimensional CIE chart. It must be represented separately.

Saturation. This is the colorfulness of the color independent of its luminance. A color's saturation is represented on the CIE chart as the distance from the white point. As a color moves closer to the white point it loses saturation. As it moves away from the white point towards the gamut boundary (this defines the limits maximum saturation of the selected gamut) it becomes more deeply saturated. Add saturation to a color and it will begin to appear more deep and rich. Reduce saturation of a color and it will begin to appear less colorful while maintaining the same luminance.

There has been an unfortunate tendency in the popular press to refer to saturation as though it were an unqualified positive aspect of a display's color reproduction and that the more of it the better. However, there is only one correct amount of saturation for any color, and that is the amount defined by the gamut being used. For all practical purposes, this gamut you should calibrate to is the high-definition standard known as Rec. 709. For more information about calibrating to different gamuts, refer to Reference Gamuts, p. 69.

Hue. This is the primary characteristic of color that allows us to distinguish one color from another. A color's hue is measured by its angle to the white point and is the primary characteristic of color. While saturation is changed by moving a color towards or away from the white point, hue is changed by rotating a color around the white point. When a color's hue is off, its appearance will seem contaminated by other colors. For example, red that is too yellowish will begin to seem orange. Blue that is too reddish will begin to appear purplish. Human vision is very sensitive to changes in hue, especially with things like skin color and natural objects (trees, sky, etc.) with which we are very familiar.

Color Luminance. This is the brightness or intensity of color. Often confused with saturation, the luminance of any color (or even white) can be measured by a simple light meter. Color luminance comes in two types: absolute luminance and relative luminance.

- Absolute luminance is the value typically expressed in cd/m2 or foot-lamberts (metric or imperial units of luminance) that is reported directly by the color analyzer. Absolute luminance is useful for determining peak output, black level, and gamma.
- Relative luminance is the luminance of a color expressed as a percentage of the luminance of reference white. The relative luminance of reference white is always represented as 1.0 and colors are shown as some percentage of that. For example, the high-definition standard for the luminance of red is 0.2126. That means that 100% red should

measure 21.26% as bright as the 100% white. Relative luminance is useful for gamut specifications and calculating color error. For more information about color error, refer to Understanding Delta-E, p. 70.

To sum up, as we have seen each color can be expressed by xy coordinates on a chromaticity chart, which establishes its saturation and hue. The Y value defines its luminance. The correct xy coordinates for all primary and secondary colors are determined by the reference gamut. If a color deviates from the reference point by appearing shifted towards other colors on the chart, then its hue is wrong and needs correcting. If a color is shifted closer to or farther from the white point in the center of the chart relative to the reference, then its saturation is wrong and needs correcting. Finally, if the color is too bright or too dim relative to the established standard (not shown on the chart, but determined mathematically), then its luminance is wrong and needs correcting.

Calibration Order

Adjustments should be made in the following order:

1. Correct the meter (optional, and only if you have a reference meter).
2. Take a full set of readings in the Pre-Calibration Grayscale and Color Gamut modules.
3. Set Black and White levels.
4. Set Sharpness.
5. Calibrate the Grayscale.
6. Calibrate Gamma. You will need to measure the grayscale again and probably readjust. Changes in gamma will effect the grayscale.
7. Adjust Color/Tint (If your display has a CMS, then Color and Tint adjustments are not necessary. The display's CMS will take care of this.)
8. Calibrate the color gamut using a CMS.
9. Measure everything again.
10. Take a full set of readings in the Post-Calibration Grayscale and Color Gamut modules.
11. Generate a calibration report.

Calibration Steps

The list below shows the main steps you should take when calibrating your display. For specific instructions on how to make these adjustments using ChromaPure software, refer to Calibration Procedures, p. 2. However, if you do not have a good background on how the process works, read this section first.

Setting White Level (Contrast)

The Contrast control determines the light output your display. Set it too low and you lose image punch and lower the contrast ratio. Set this too high and you lose color accuracy and detail in bright scenes. Setting contrast too high can also cause eye strain, image noise, and premature aging of the display.

The standard method for setting Contrast requires that you look at a test pattern that has a just-below-white stripe against a white background. You set Contrast as high as you can without losing the ability to distinguish the just-below-white stripe from full white.

However, there are a couple of problems with this method.

- Many modern digital displays will never suffer from loss of high level detail even with Contrast set to 100%. This method will recommend a setting that is much too high.
- This method does not take into consideration color performance. Many displays will lose color accuracy when Contrast set as high as this method recommends.

A better method for setting Contrast is a three-step process:

1. Adjust the contrast control so as to achieve a reasonable light output for a given display device. What's a reasonable level? Direct view displays, such as CRTs, plasmas, rear projection, and OLED and LCD flat panels should be set to around 120 cd/m2 (35 fL). You can set it a little higher if you prefer, but I wouldn't go over 150 cd/m2. Set digital front projectors at 48 cd/m2 (14 fL). HDR displays will provide brighter images.
2. Check a contrast test pattern as described above to ensure that just-below white is not clipped. It is also probably a good idea to not clip just-above white either. Most contrast test patters include -2% and +2% stripes against a white background. Both should be visible.
3. Check the white balance at 100%. If a neutral white cannot be maintained, then you should lower the contrast. This can especially be a problem for digital front projectors whose bulbs lose output capacity fairly quickly.

These values come from the SMPTE standard, which is always useful in such matters. EBU recommends a lower value (80 cd/m2) for direct view displays, but most viewers will prefer the higher light output recommended by SMPTE.

Setting Black Level (Brightness)

You should set black level by eye using test patterns. You want to set the black level of the display as low as you can without losing the ability to see video information that is just above black. If you set black level too low, then you will lose shadow detail (this is sometimes referred to as “crushed blacks”). If you set black level too high, then you lower the display's contrast and realism in dark scenes.

The typical method for setting black level is to use a test pattern that displays a just-below black stripe and a just-above black stripe against a black background. You set brightness so that the just-above black is barely visible and the just-below black is invisible.

There is one problem with the method just described. How do we set black level for broadcast sources where no test pattern is available? Fortunately, there is one approach that will get a correct black level even without a test pattern, but you must have a recorded source of broadcast material, such as from a DVR.

1. Record a television source that includes a "fade to black" sequence that typically occurs in between commercials or between commercials and network programming.
2. Play back the sequence and pause at the "fade to black" section.
3. Using a colorimeter or a light meter, measure the light output of the black screen.
4. Adjust the black level up and down. You will find a place where additional downwards adjustments of the Brightness setting will not affect the light output of the panel. That point just where the panel's light output becomes unresponsive to decreases in the Brightness setting is the correct setting for black.

Setting Sharpness

This should also be adjusted by eye. Use a sharpness test pattern, which is generally a series of horizontal and vertical lines, to look for ringing or faint outlines along the edges of the lines in the test pattern. Set the Sharpness control to the highest point you can that minimizes ringing (you may not be able to eliminate it entirely). On some sets, the sharpness should be set to zero. But for many it is somewhat higher than this.

Adjusting White Balance

Briefly, white balance adjustment simply involves adjusting specialized controls that allow a display to render a neutral white throughout its entire range from the blackest black to the whitest white.

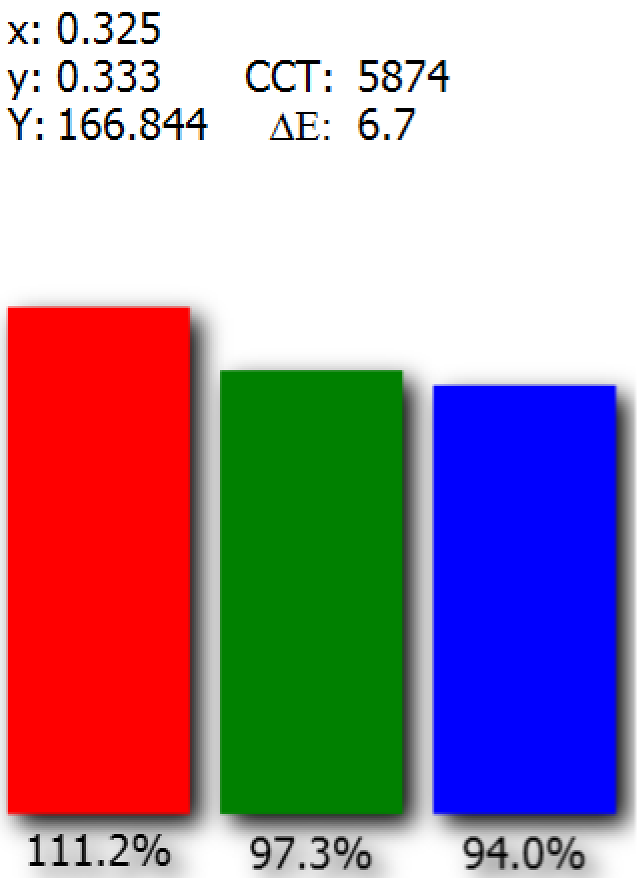
Unlike a good color management system (CMS), which is not common, virtually all displays have white balance controls. Sometimes they are in the user menu, or they may be buried in a service menu that can only be accessed by a specific key sequence on the remote. The goal is to get an xy measurement as close as possible to x0.3127, y0.329, which is equivalent to red, green, and blue all being at 100% relative intensity. Since white is the combination of the three primary colors, neutral white is achieved when those colors are in relative balance. The calibration software will provide these raw numbers and a graphical representation of RGB relative to the target white point.

To calibrate the white balance:

1. Aim the meter at the display.
2. Select a 80% gray test pattern.
3. Adjust the RGB Contrast controls until RGB is balanced or until you read close to x0.3127, y0.329.
4. Select a 20% gray test pattern and use the RGB Brightness controls until RGB is balanced or until you read close to x0.3127, y0.329. Repeat the last two steps as many times as necessary until both the 80% gray and the 20% gray test patterns measure a neutral shade of white. This may take several rounds of measurements back-and-forth.

5 Finally, take an entire series of grayscale measurements at 10% intervals from 5% or 10% to 100% to ensure that the display tracks white accurately throughout the entire range.

Consider the example below. This is not a neutral shade of white, because there is too much red and insufficient blue and green. You would adjust your display's white balance controls until these three bars all measured as close to 100% as possible.



Sometimes you may find that even though 80 and 20% stimulus are neutral white, the mid range 40-60% stimulus is not. This means that your display won't track a good grayscale and you have to make some compromises. The general rule of thumb is to focus on getting the mid range to track neutral white. Then get the low end right. Sacrifice accuracy at the top end if you have to.

NOTE: There is no industry-wide accepted terminology for white balance controls. You may see RGB Contrast/Brightness, RGB Gain/Bias, RGB Gain/Offset, RGB Drives/Cuts. They all mean the same thing. Contrast, Gain, or Drive is for adjusting the bright end of the grayscale and Brightness, Bias, Offset, or Cut is for adjusting the dark end of the grayscale.

Setting Color/Tint

The standard method for adjusting color and tint involves looking at a SMPTE color bar test pattern through a blue filter. This method has 2 drawbacks. First, at best it is an approximation of the correct setting. Second, and more importantly, for some displays it simply does NOT work. On some plasmas in particular I have noticed that this method will recommend a grossly inaccurate setting. Here's a foolproof method for setting Color/Tint that does not use filters.

Color

1. Point the colorimeter or light meter towards the screen and display a 100% white test pattern.
2. Measure the Y value (luminance) of white.
3. Display a 100% Red test pattern, and measure the Y value here as well. You will notice that as you move the Color control up and down, the Y value of Red increases and decreases, but white stays the same.
4. Set the color control at the point where Red Y measures closest to 21% of the white reading.

Tint

1. If you have not already done so, adjust the gray scale and get it as close to accurate across the entire range as possible.
2. Point the color analyzer towards the screen and display a cyan test pattern.
3. Put the Tint control at its neutral mid setting.
4. Use the software controls to plot the hue of cyan on a CIE chart.
5. Adjust Tint up or down until the reading places the hue of cyan as close to the target as possible.
6. If you had to substantially adjust Tint from the neutral point to get an accurate hue of cyan, then check the other secondary colors—yellow and magenta—as well. You may have to select another setting that gets the average error in hue of the three secondary colors as low as possible.

TIP: If your display has a full-featured CMS, then adjusting the main Color and Tint controls is not necessary.

Adjusting Color using a Color Management System (CMS)

1. Point your colorimeter towards the screen, display a white window, and then take a xyY measurement.
2. Repeat the step above for all of the primary and secondary colors (red, green, blue, yellow, cyan, magenta).

3. Use the controls on your calibration software to plot the amount of error in hue, saturation, and brightness each color shows relative to the chosen standard. I would select the Rec. 709 (High-Definition) standard. Your software should allow you to set that as the target gamut.
4. Use the CMS on the display to adjust the colors so that they show the lowest error in each of the 3 dimensions as possible. dE is a good single numerical metric for judging the amount of color error. The lower the dE value, the better. For more information about dE, refer to Understanding Delta-E, p. 70.
5. You probably won't be able to get all of the colors lined up perfectly, but get them as close as you can.
6. It is important to understand that some poorly designed CMSs are such that as you change the xy values to get correct hue/saturation of a color and a good looking CIE chart, the Y value (luminance) will change as well. Since the CIE chart doesn't show luminance, it is very important that you check this after making these changes. Otherwise, you could have made the color worse without knowing it. If your software doesn't support direct read-outs of color luminance, then you'll have to do it manually. The luminance of each color should be a close as possible to the Y value specified by the target gamut. Remember, these Y values are relative luminance, so they are just percentages of reference white. You'll have to measure the luminance of white first, and then check the luminance of the colors to see how close they are to the specified value in the gamut. For more information about various reference gamuts, refer to Reference Gamuts, p. 69.

NOTE: The human eye is not equally sensitive to all colors and all color differences. For example, it is more important to get red and green right than blue. It is also more important to get correct hues than correct saturation.

Adjusting Gamma

You want to ensure that your display has a gamma response that is both within the accepted range and that it is reasonably linear. I suggest 2.22 as a good gamma value to aim for, but you can experiment with somewhat higher gammas if you like. Above 2.35 you will likely find that the image loses shadow detail and begins to appear somewhat contrasty.

1. Display a 100% white test pattern and record the Y (brightness) value.
2. Display a 90% white test pattern and record the Y (brightness) value.
3. Repeat until you have recorded the intensity of white all the way down to 10%.

ChromaPure will plot the gamma values at each of these levels. Use your display's controls to make necessary adjustments to achieve a gamma value as close to the target as possible at every point throughout the grayscale.

That's it. Now you should go back and remeasure black/white levels, gray-scale, color decoding, saturation/tint, and gamma because there may have been interaction between these adjustments. You may have to go through two or three rounds of measurements until all are correct.

Calibrating a Front Projector

Calibrating front projectors poses some special issues primarily concerned with the fact that, unlike flat panels, you can measure projectors in two ways: off the screen or directly from the projector's lamp. SMPTE recommends that all critical measurements should be taken at the viewing position from the center of the screen. Because of the limitations of most consumer color analyzers, measurements should generally be taken closer to screen, say a foot or two. Also, angle the meter slightly so it does not read its own shadow.

If you have a high gain screen, then you should be careful to keep this angle as small as possible. This is because high gain screens will color shift off axis.

There are some circumstances in which measurements directly from the lamp are useful.

- **Contrast:** Since the light reflected off the screen is minimal when projecting black, you will probably get a more accurate reading by taking measurements directly from the lamp. Compare this to a measurement of full white to get contrast ratio. Since you don't have to worry about angle of acceptance or screen gain, reading the light output directly from the lamp is generally easier and probably more accurate than reading reflected light off the screen. To ensure accuracy, do not move the sensor between the two readings. A standard camera tripod is useful for this.
- **Exotic screens:** Projection screens with a very high gain cannot be measured reliably off-axis, which makes reading from the screen difficult. If you have such a screen, it may be best to read directly from the lens.

Some additional points to consider.

- **Use a diffuser:** Whenever you take readings directly from the projector lamp you must install a diffuser on the meter. All of ChromaPure's supported meters are luminance devices and do not support reading directly from a projector lens without the use of a diffuser.
- **Consider an illuminance meter:** Alternatively, you can use a lux meter (such as the AEMC CA813) for contrast and gamma readings, but not for readings that require color information. Illuminance meters read in lux rather than in fL or nits. ChromaPure includes a lumens calculator for calculating fL, nits, and lumens from lux measurements from such a device. For more information on the lumens calculator, refer to Calculating Lumens for a Front Projector, p. 59.
- **Use Color Correction:** Finally, if you do take color readings directly from the lamp using a meter and diffuser, you should also take readings with the same meter off the screen and use those to create a reference to color correct the direct-from-lamp readings. For more information on creating an offset using ChromaPure refer to Creating A Meter Correction, p. 26. Of course, this assumes that you can take a good reading from the screen, and you may not be able to if you have an exotic screen (see above).
- **Meter Placement:** When reading from the screen place the meter 1-2 feet from the screen angled slightly to the right or left to avoid reading the meter's shadow. When

reading from the lens place the meter close enough it can measure black, but not so close that full white overloads the meter.

- **Test Patterns:** For all digital front projectors, use full field test patterns. For CRT projectors only, use window test patterns.

Calibrating UHD sources

Overview

Calibrating UHD sources pose some special problems. First, the native gamut of the medium, Rec. 2020, is an extremely wide gamut that no commercial display can come even close to reproducing. Second, all UHD discs offer High Dynamic range, or HDR, whose specification requires a peak luminance that, again, no commercial display can come even close to reproducing.

When there is such a profound discrepancy between what the standard requires and what the display technology allows, decisions need to be made as to how UHD sources should be calibrated. We recommend three important steps:

- Select HDR10 gamma in the Options module. When calibrating gamma and grayscale do not expect to be able to achieve the specified targets beyond 60%-70% video. Current displays are simply not capable of producing the output that would be required to meet the full HDR standard out to 100% video. If you are calibrating a projector, then use the HDR10-Projector gamma. Under HDR Projector, select a number between 3000 and 6000. These numbers correspond to the light output of the projector. The greater its light output, the higher the number you should select. 4000 or 5000 are good starting points for most projectors.
- Select the Rec. 2020 reference gamut also in the **Options** module. Further, when using the Color Management module select 50% intensity and 50% saturation targets.
- Use special test patterns explicitly designed for HDR. Regular test patterns will not work properly.
- Set the saturation increments to 25%. This ensures that 50% saturation will be available for reporting purposes.

In all other respects UHD calibration is no different than calibrating standard Blu-ray or DVD sources.

Chapter 2: Pre-calibration Procedures

What's Inside?

Installing and Configuring ChromaPure for Initial Use

Overview

To get ChromaPure fully up and running you need to accomplish six tasks.

1. Install .Net
2. Install ChromaPure Software
3. Import the license file
4. Install a driver for your color analyzer
5. Select and Initialize your color analyzer
6. Select and setup your test pattern source

Each of these steps is covered below.

Install Microsoft .Net Framework

Install the Microsoft .Net 4.6.1 or higher framework if your PC does not already have this. The .Net installation file may be downloaded from the Internet.

Once .Net is installed, you are ready to install ChromaPure Software.

Install ChromaPure Software

To install ChromaPure, just double-click the Cp3Setup.exe file you downloaded from the Chroma-Pure web site and follow the on-screen instructions.

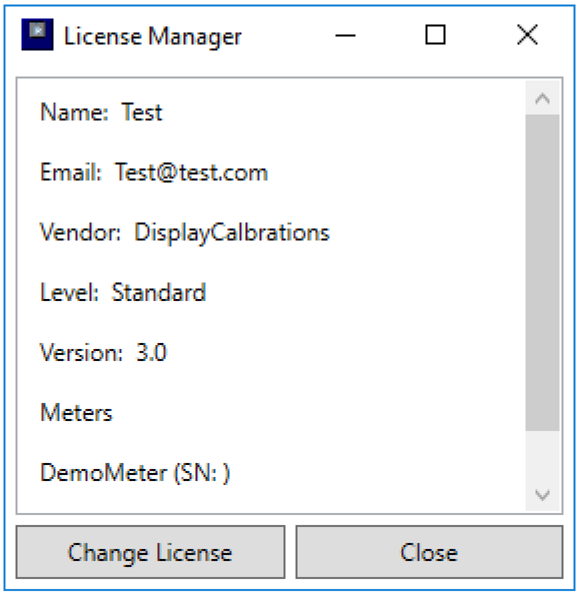
When installation is complete, a ChromaPure icon will appear on your desktop.

Import the License File

You will now need to install the license file that you were provided when you purchased the software. This file includes the serial number of the color analyzer you were licensed to use with ChromaPure.

To import a license file:

1. Start ChromaPure by double-clicking the desktop icon.
2. The first time ChromaPure runs, you will be prompted for a license file.



3. Click **Change License**, and then browse to the location where your license file has been saved.
4. Select the license and then click **Open**. Your license file will be installed.

TIP: If you ever need to install a new license, you can access the **License Mgmt.** from the main interface.

Install a Driver for the Color Analyzer

Overview

Before you can use your color analyzer, whether it is a tristimulus colorimeter or a spectroradiometer, you may have to install a driver so that Microsoft Windows can communicate with it.

To install a driver in Windows 7/8/10:

1 Plug the meter into an available USB port.

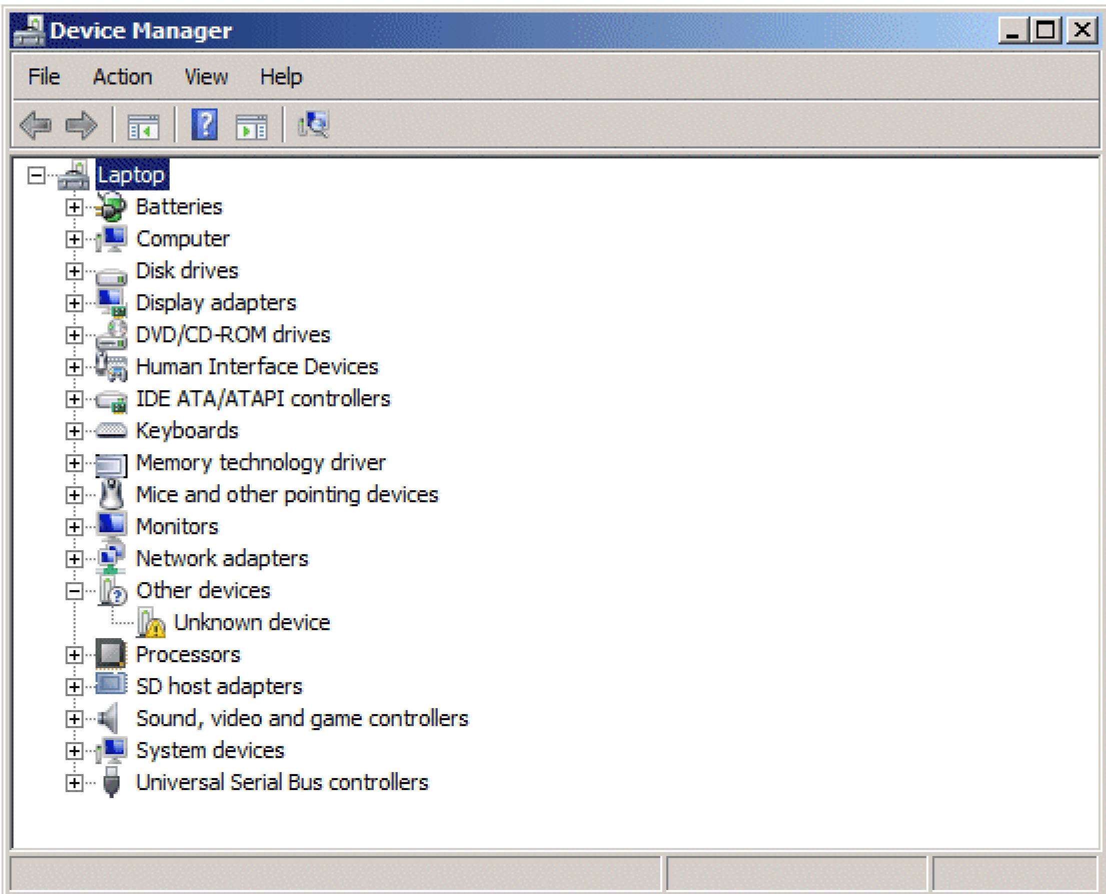
You will see a message informing you that the device is not working.

2 Close this message.

3 Open the Windows **Control Panel**.

4 In the **Control Panel**, navigate to **System**, **Device Manager**.

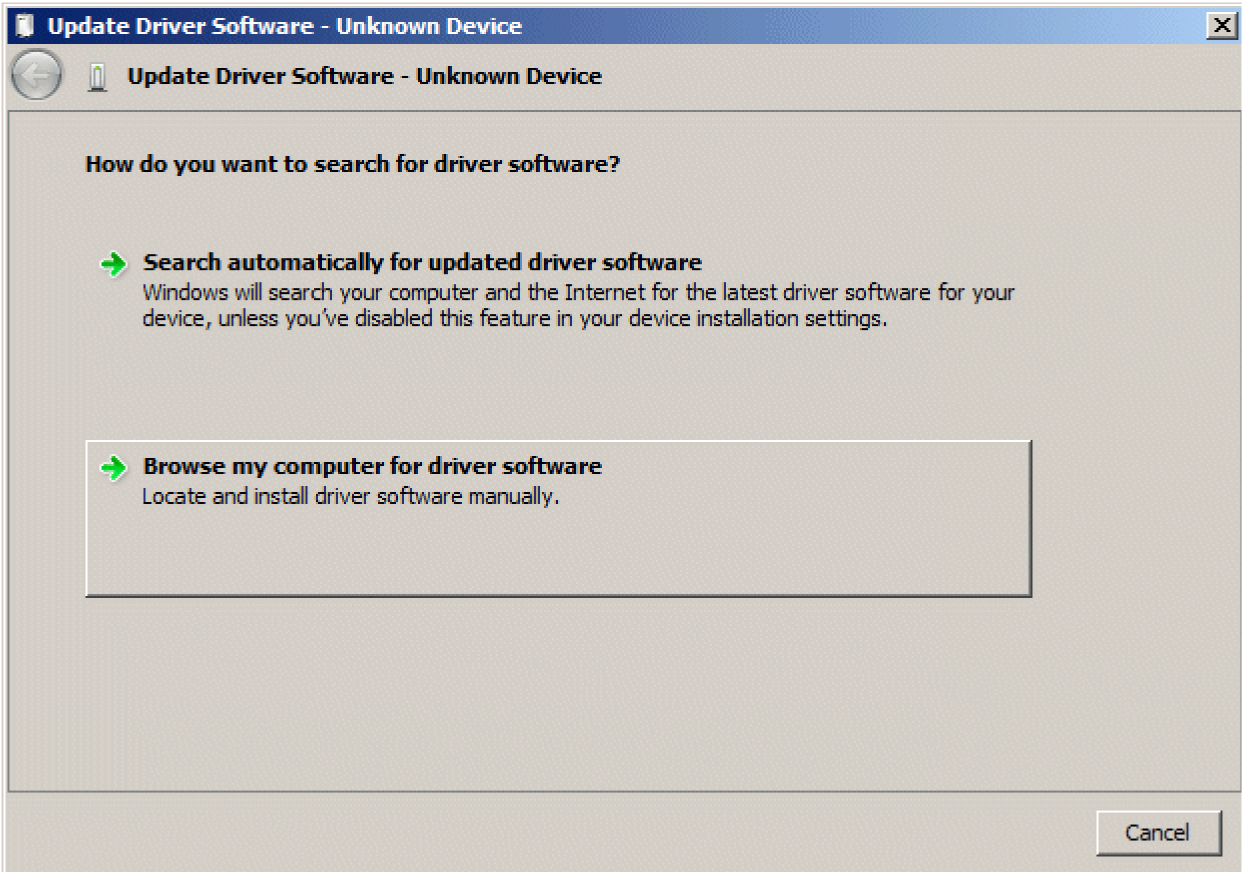
The Windows **Device Manager** will appear.



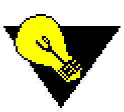
You should see an item with a yellow exclamation point probably under "Other Devices" indicating that the driver is not installed.

5 Right-click that item, and then select **Update Driver Software**.

An **Update Driver Software** window will appear.



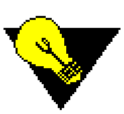
6 Click the **Browse my computer for driver software** button, and then browse to the location on your hard drive that contains the driver files



TIP: ChromaPure includes a Drivers zip file containing the necessary drivers. You should unzip this to an easy location, such as the Desktop. You may need to set ChromaPure to be run as an administrator. There are several sub folders under Drivers. Select the one that contains the driver for your device (For example, if you are installing the XRite i1Pro or Display 2, then select the i1ProD2 sub folder. If you are installing the DataColor Spyder 5, then select the Spyder5 sub folder.)

7 Click **Next**. A final **Update Driver Software** window will appear.

8 Click **Close**. You are now ready to begin using the meter in Windows.



TIP: The popular X-Rite i1Display Pro meter does not require driver installation. Its driver is built-in to Windows.

Selecting and Initializing the Meter

Overview

Prior to any calibration session, you must have a color analyzer connected. ChromaPure Standard supports all of the popular color analyzers. Consult the ChromaPure web site for a comprehensive list.

Any of the supported color analyzers can be upgraded to a PRO version. This indicates that the colorimeter's response has been corrected by a reference instrument using a matrix correction built in to the ChromaPure license file. No change is made to the hardware device itself.

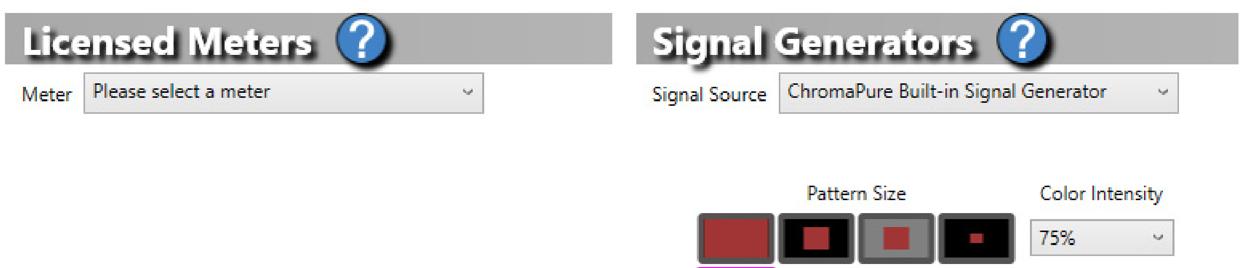
We continually review the hardware options available and add new meter support when appropriate.

Color Analyzers measure both the chromaticity and luminance of light. The measurements are reported in xyY format. xy coordinates describe chromaticity and Y describes luminance in either in candelas per square meter (cd/m2)or foot lamberts (fL). Luminance is the diffuse light we receive from flat panels or projector screens. If you wish to read light directly from a front projector's lens, you must attach a diffuser to the meter's lens. For more information about calibrating a front projector, refer to Calibrating a Front Projector, p. 12.

To prepare a meter for a calibration session:

1. Attach the meter to your PC's USB port.
2. From the main ChromaPure window, click the **Initial Setup** icon.

   The **Initial Setup** module will appear.



3. Select the desired licensed meter from the drop down.

A **Connect** button and a mode selection drop-down will appear.

4. Select the desired operating mode. Some meters only have one operating mode.
5. Click **Connect**.
6. If the meter requires a dark reading, place against a flat surface to block out all light. For more information about the dark reading requirements of various color analyzers, refer to Dark Reading Requirements, p. 68.

TIP: If the selected meter relies on a serial connection—such as the Klein K10—you will have to set the serial port settings. This usually involves only setting the correct port, which you can determine by looking in the Windows **Device Manager**. Click the button to the right of the operating mode drop-down to access the serial port settings.

Selecting and Configuring a Test Pattern Source

If you have test patterns on a Blu-ray disc, you can provide test patterns manually. However, you may want to automate your calibration sessions. You can do this by using a signal generator. ChromaPure Standard currently supports the following devices as signal generators:

- The computer's video card
- DVDO iScan Duo
- Lumagen Radiance

A signal generator will provide both standard color and grayscale test patterns along with specialized test patterns that require visual inspection, such as a black/white pluge, crosshatch, and multiburst. These special test patterns can be accessed from a drop-down in the upper-left of the main application window. If you are using the DVDO Duo or Lumagen, then you can also use the Manual Control toolbar, which you can start by clicking the Generator Control icon on the main ChromaPure window. For more information about the Video Processor Manual Control Toolbar, refer to Using Video Processor Manual Control, p. 49.

Using any of these options, ChromaPure will automatically display the correct test pattern required by the feature you access within the application. No user intervention is required.

Using Test Patterns from a Blu-ray or DVD Disc

By default, ChromaPure is ready to use a Bluray or DVD disc as a test pattern source. If you wish to do this, then no further action is necessary other than setting the desired Intensity (100%, 75%, or 50%). If are using another test pattern source, and you wish to revert to using a disc, then simply select Calibration Disc from the Signal Generators drop-down on the Initial Settings module.

Using automation with the PC's video card

The easiest way to automate test patterns is to enable ChromaPure's Built-in signal generator. This is available for any computer that has a HDMI out port that you can connect to your display. Then, you only need to setup Windows' extended display feature to use both the computer's own monitor to display the application and the display you are calibrating on which the test patterns would appear.

On ChromaPure's Initial Setup page:

1. From the Signal Generators drop-down, select **ChromaPure Built-in Signal Generator**.
2. Select a **Pattern Size** and **Color Intensity**.
3. Plug in an HDMI cable into your computer that connects to the television you wish to calibrate.
4. Configure the TV you are calibrating with the Windows extended display feature so that the video card outputs its native resolution, which will usually be 1920x1080, and simultaneously allows you to use the computer display to run ChromaPure. ChrtomaPure should display on your computer’s display.
5. Drag the test pattern onto the secondary display—the display being calibrated—and then right-click on the test pattern and select **Maximize**.

With the Built-in signal generator activated, the proper test patterns will now appear automatically as you use various features in the application. You may also now call up any one of the many specialized test patterns from the signal generator drop-down.

Using madVR

You can also use madVR to generate test patterns from the PC’s video card. We recommend this option if you want to generate HDR test patterns. madVR will generate these if your video card supports it. Use the ChromaPure Built-in test patterns for SDR.

Using automation with an external video test pattern generator

ChromaPure Plus and ChromaPure Professional add support for several external signal generators. Check the ChromaPure web site for a list of supported generators.

To use an external signal generator:

1. Connect the generator to the PC via USB (it may require a serial/usb adapter and a driver), and then connect the signal generator's output to the display you wish to calibrate.
2. From the Initial Setup module, select **External Signal Generator** from the **Signal Generators** drop-down.
3. Select the desired generator from the list of supported generators, and then click **Connect**.

   The selected signal generator will appear.
4. Click the radio button next to the selected generator.

5 Select the correct serial port. You can verify this by looking in the Windows **Device Manager**. Please use a port of 4 or higher. Most generators use a 9600 baud rate. The DVDO Duo uses 19200 and the DVDO TPG and Murideo use 115200.

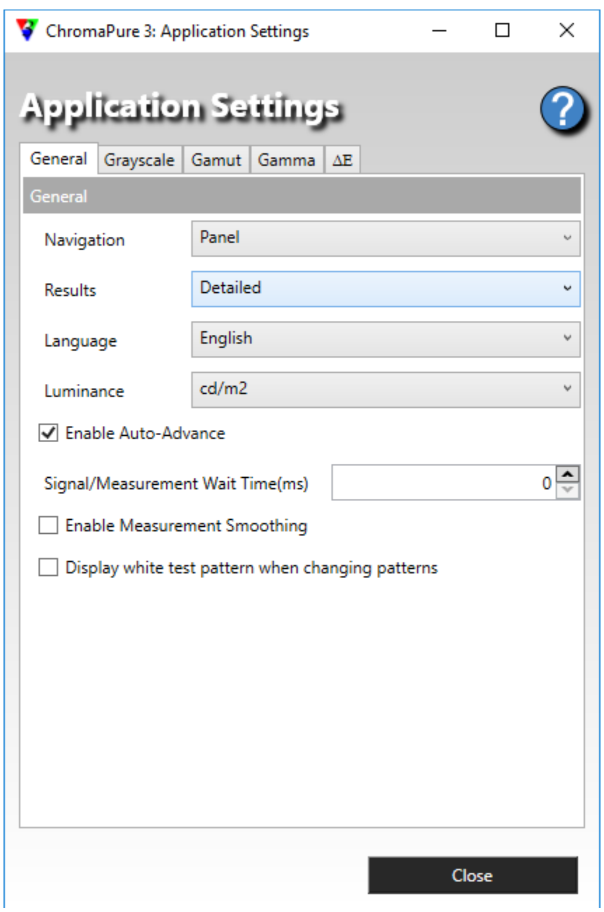
- Select the desired output for the generator, including:
- Color Format
- Resolution
- Intensity
- Pattern Size

You are now ready to use the signal generator.

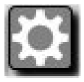
Selecting Application Options

Overview

Before beginning your calibration session, you will probably want to set the options that you desire. To do this, click **Options** on the main ChromaPure window.



You can also access application settings from within many of the modules by clicking the **Application Settings** icon



For detailed information about the various settings, refer to Selecting Application Options, p. 21 above.

ChromaPure offers the following options in the **Application Settings** module.

General

Navigation

This option allows you to select between two UI's, Panel (the default) and Horizontal or Vertical icons.

Results

Most modules have a color list panel on the left side of the screen. This allows you to toggle between a detailed view and a more compact view that saves screen real estate.

Language

This option allows the user to select the application's language preference. The available preferences are currently English, French, and Spanish.

Luminance

The two options provided are cd/m2 (candelas per meter squared) or fL (Foot Lamberts). Either measures the luminance of the signal. Cd/m2 (sometimes called nits) is a metric unit and fL is an Imperial unit. 1 cd/m2 equals 0.2919 fL and 1 fL equals 3.426 cd/m2. Choosing which to use is merely a matter of preference. It does not affect the substantive results, but only how they are displayed.

Signal/Measurement Wait Time (ms)

Some signal generators may require a small wait time to get the test pattern appearance and measurement properly synchronized. By default, this is set to 0 ms. Leave this alone unless you are experiencing problems.

Enable Auto-Advance

This option allows the application to automatically advance to the next measurement in a series. It is checked by default.

Measurement Smoothing

With some meters you may notice that at very low light levels results bounce around considerably making it difficult to determine with any precision the value of the reading. The Measurement Smoothing option addresses this problem.

There are couple of issues to consider when using Measurement Smoothing.

- It will slow the application's ability to return data.
- This feature only works for single readings. The Continuous mode has its own averaging built-in, so Measurement Smoothing is disabled here.
- Do not use Measurement Smoothing for auto-calibration

Display white test pattern when changing patterns

This option inserts a white test pattern in between each measurement. This is useful if the display includes brightness limiting technology that automatically dims the image in the presence of static test patterns.

Grayscale

Increments

Select either 12 point (10% increments with a 5% reading) or 21 points (5% increments).

Max White

Select the application's white point: 100% (235 default), 104% (250), 109% (255)

Gamut

When calibrating a display, you need a reference gamut. Each gamut specifies the hue and saturation for the primary colors (red, green, and blue) and a white point. From this is calculated the saturation and hue of the secondary colors and the luminance of all of the colors.

ChromaPure offers six reference gamuts.

- SMPTE-C
- Rec. 709
- EBU
- DCiP3
- Rec. 2020
- Adobe RGB

Use SMPTEC for NTSC standard definition, Rec. 709 for NTSC and EBU-based high definition in Europe, and EBU for PAL-based SD material in Europe. DCi-P3 (Digital Cinema Initiative) is an expanded gamut for which consumer material is not currently available, but which may be useful for UHD discs. Use Rec. 2020 for UHD only. The Adobe RGB gamut is widely used in the photographic content. For more information about the standard gamuts, refer to Reference Gamuts, p. 69.

Gamut White Point

You should generally not change this. Leave it at the default of 0.312727, 0.329023, 1.0. However, in unusual cases it may be useful to change the white point for the selected **Reference Gamut**. For example, you may want to calibrate the display to use a warmer white that was often used in old black-and-white films. Another circumstance is when measuring your display results in metameric failure. For more information about Metameric failure, refer to Metameric Failure, p. 38.

The white point will always revert back to the default with each new calibration session.

Enable Gamut Overlay on CIE Charts

You can opt to display a secondary gamut on top of the Reference Gamut. This is useful when using Rec. 2020. It allows you to see where your measurements fall relative to more realistic gamuts, such as P3 or Rec. 709. If you also select **Use overlay gamut as calibration target**, the calibration results will be based on the overlay gamut, though the test patterns will be based on the reference gamut.

Saturation Increments

The Color Gamut and Performance modules offer measurements of various levels of color saturation. Use this selector to pick between 25% (4 levels of saturation) or 20% (5 levels of saturation). Be sure to always use 25% increments for HDR calibrations.

Gamma

Gamut Target

Select the system-wide gamma here. You can select one of several gammas (we recommend 2.22 in most cases), sRGB, or BT.1886. BT.1886 requires you to specify the white and black level of the display, and the entry form for this is provided below. You can also select HDR10 or HDR10 Projector.

HDR Projector

This drop down offers selections from 3000-6000. Select the largest value that allows you to maintain proper gamma response for an HDR10 signal on your projector out to 60%. The value will vary depending on the light output capabilities of your projector.

Black Level and White Level

These are the values used to calculate BT.1886 gamma and other calculated gammas. In most cases, you can probably just leave the values at their defaults, 0.03 and 120.

dE Method

Delta-E (dE) is a measurement of color error relative to a standard. Thus, the goal in calibration is to get the dE of the measured color as low as possible. There are different dE formulas that provide somewhat different results. ChromaPure offers four options:

- CIELUV
- CIELAB
- CIE94
- CIE2000

Both CIELUV and CIELAB were endorsed by CIE in 1976. The underlying formula in each is the same, but they rely on different color spaces. Because Luv offers a linear chromaticity diagram, it is more commonly used for video applications, but Lab is a perfectly acceptable alternative. In fact, SMPTE has recently endorsed CIELAB as the color difference metric for its Digital Cinema Initiative. CIE94 was developed by CIE in 1994 and is based on Lab only. It is a more complicated formula than the 1976 alternatives and arguably provides more accurate results, especially with color. CIE2000, endorsed in 2000 by CIE, is an even more complicated formula that has never gained widespread acceptance outside of the textile industry. It is also Lab-based.

It is important to understand that these different measurements of color error scale somewhat differently, so when comparing results obtained by different dE formulas, use the following equivalence scales:

For white

- CIELUV 4.0
- CIELAB/CIE94/CIE2000 3.0

For color

- CIELUV 4.0
- CIELAB 3.0
- CIE94 1.5
- CIE2000 1.5

Which dE formula you use is to a certain extent a matter of personal preference. However, we recommend using CIE94 for primary/secondary color grading. For simplicity's sake, you could use CIE94 for grayscale also. It will return the same results as CIELAB. However, many prefer CIELUV for grayscale as it is somewhat more sensitive to small color errors. The targets for color measurements when using the newer formulas are different because of the manner in which the newer formulas treat luminance in the calculation, which is ignored for grayscale. Luminance performance with respect to grayscale tracking is part of the gamma response of the display and plays no role in dE calculations.

Creating A Meter Correction

Overview

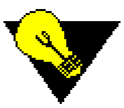
Meter correction is an optional feature that allows a calibrator to use a reference meter to correct the response of a faster, but less accurate, field device.

Many low-cost colorimeters are easy to use and offer very good low-light sensitivity, but lack precise color accuracy, especially for certain types of displays. At the same time, many spectroradiometers offer reference color accuracy, but can be slow and often have poor low-light sensitivity. The **Meter Correction** feature allows you to adjust the response of the colorimeter to match the performance of the reference spectroradiometer. The result is the best of both worlds. You can now calibrate displays with a device that is fast, easy to use, color accurate, and good at low light levels.

You can also use the **Meter Correction** feature with front projectors when you wish to measure directly from the projector lens. Use measurements taken off the screen to correct the readings taken directly from the lens.

To create and use a meter correction:

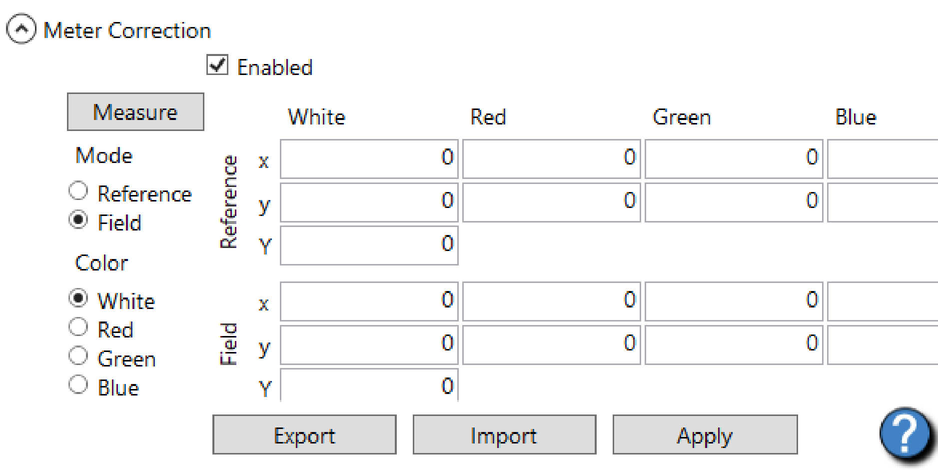
1 Select and Initialize the reference meter.



TIP: You can use the Meter Correction feature even if ChromaPure does not support the reference device. In this case, simply measure RGBW with the reference meter, record the results, and then manually type the xy values into the appropriate reference fields in the **Meter Correction** module. Then proceed with Step 4 below.

2 Click the **Meter Correction** drop-down from the **Initial Setup** module.

The **Meter Correction** module will appear below the **Meter Setup** section.



3 Select the **Reference Meter** radio button, and then take a series of WRGB measurements.

4 Disconnect the reference meter. Also, it is best to physically unplug the reference meter.

5 Plug-in your field meter and initialize it. For information about how to setup a meter, see Selecting and Initializing the Meter.p. 24

6 Return to **Meter Correction**.

The reference fields will be populated with the values you already measured.

7 Select the **Field Meter** radio button, and then take a series of WRGB measurements.

ChromaPure will automatically calculate the correction between the Reference and Field meters.

8 Once all of the corrections have been calculated, click the **Apply** button.

The correction will now be applied to all measurements for this session, and the field meter will emulate the performance of the reference meter.

Saving and Reusing Meter Corrections

Once you have created a meter correction, it may be useful to use it for subsequent calibration sessions. This is easy to do.

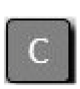
After defining and applying a meter correction, just click the Export button. and save the *.cbin file at a location with a name of your choosing. During a subsequent calibration session, after initializing the field meter, just click the Import button on the **Meter Correction** module and select the previously saved correction file. Do this will populate the correction fields. Then click **Apply**.

Taking Measurements in ChromaPure

At the top of most of the modules in ChromaPure there is a toolbar that contains all of the measurement tools.

Click **M** to take a single measurement

Click **C** to take continuous measurements

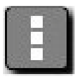


Click **A** to measure all of the colors in the module

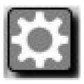
Click the red **X** to stop a measurement cycle

Click to run a Quick Report

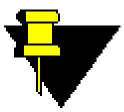
Click to access module options



Click to access application options

If  using a signal generator, then you can click **A** to measure all of the colors in the module at If you are using a DVD or Blu-ray disc, then you should click **M** to measure and then advance the disc t the next test pattern before clicking **M** again.

To take a customized set of measurements within a module, you can always just use the desired color and then use the **M** command for each measurement you wish to take. Also, if the measurements are contiguous (and you are using a signal generator), you can select the first in the list and then click **A**.



NOTE: You must always measure a white reference before measuring any color in a module. There is a white reference for pre-calibration, calibration, and post-calibration, so if you have measured a white reference in one module, then it will transfer to all other modules in that category.

Taking Pre-calibration Grayscale Measurements

Overview

The Pre-Calibration Grayscale module allows you to measure the ability of the display to track a neutral color of white from black all the way to peak white. The initial grayscale reading provides a snapshot of the display's pre-calibration performance for both white balance and gamma. You should take pre-calibration grayscale readings for every calibration session. This data is crucial if you wish to generate a before/after report.

To take an Pre-Calibration Grayscale measurement:

1 Click the **Pre-calibration Grayscale** icon.

The **Pre-calibration Grayscale** module will appear.

2 Display a 100% test pattern.

3 Click **M** to measure a 100% white reference.

ChromaPure will take a measurement of the xyY values of the white reference and automatically advance to the next level.

At this point you may continue to take measurements in this module in a number of ways. For information about how to take measurements in ChromaPure, refer to Taking Measurements in ChromaPure, p. 27.

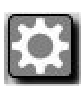
When you have finished the grayscale readings, several data elements are available.

- You can review the dE values.
- You can review the gamma values.
- You can review the Correlated Color Temperature (CCT) values.
- You can review both the gamma response and the RGB values at each video level from the provided graphs.
- You can generate a Quick Report of those graphs.

Module Options

Overview

Most modules have options that provide some flexibility to the user who wishes to work with the data. To access the module options, click



The Pre and Post-calibration Grayscale modules include three options.

- Selectable number of grayscale points. You can measure 12point or 21point grayscale.
- Selectable dynamic range. You can measure from 0%100% (default) or 0%104% or 0109%.
- Export Measurements. You can export the measured xyY values as a csv file for additional data analysis.

Taking Pre-calibration Color Gamut Measurements

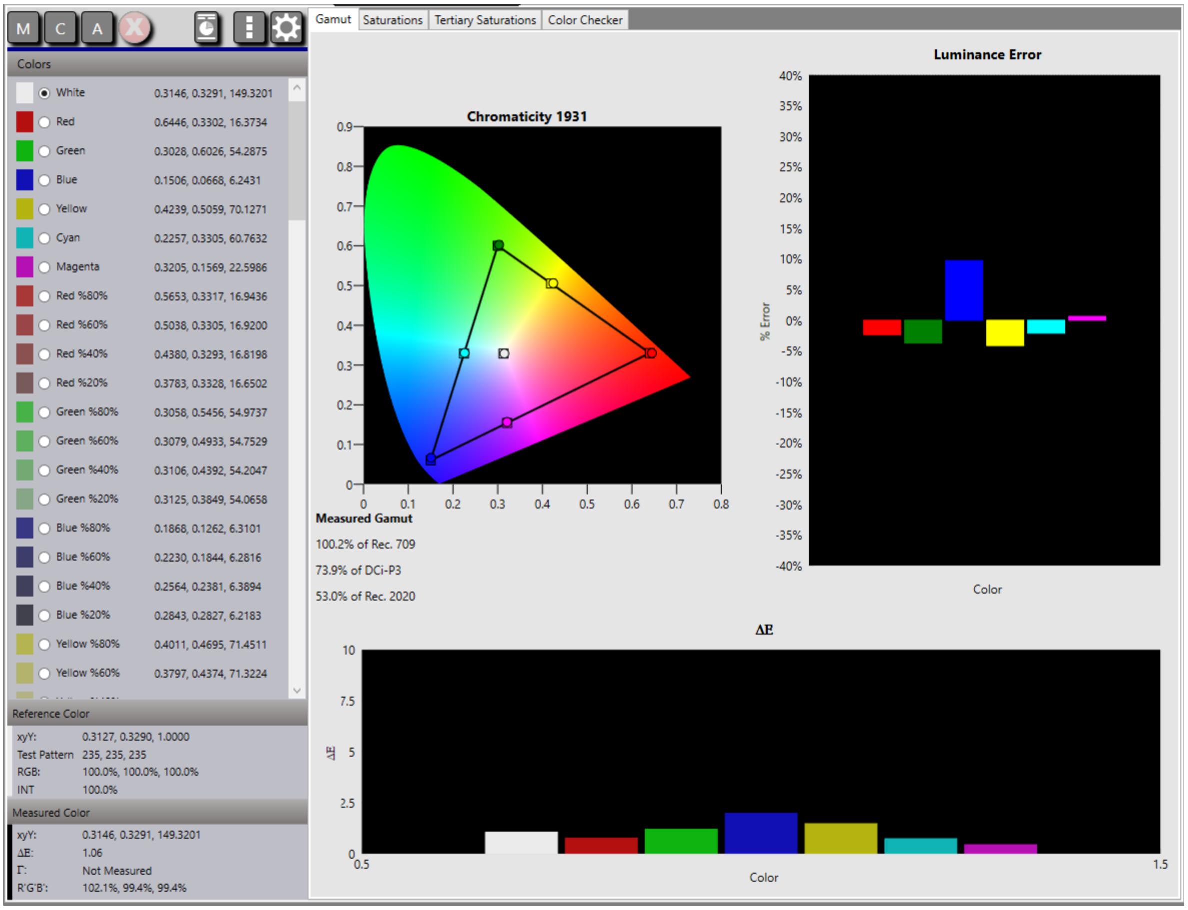
Overview

The Pre-Calibration Color Gamut module allows you to measure the display's ability to track accurate colors relative to the reference gamut. The initial gamut reading provides a snapshot of the display's pre-calibration performance for the hue, saturation, and luminance of the primary and secondary colors. You should take a pre-calibration gamut reading for every calibration session. This data is crucial if you wish to generate a before/after report.

To take a pre-calibration color gamut measurement:

1 Click the **Pre-Calibration Color Gamut** icon.

The **Pre-Calibration Color Gamut** module will appear.



2 Display a 100% white test pattern.

3 Click **Measure**. ChromaPure will take a measurement of the xyY values of white and automatically advance to the next color.

At this point you may continue to take measurements in this module in a number of ways. For information about how to take measurements in ChromaPure, refer to Taking Measurements in ChromaPure, p. 27.

When you have finished the grayscale readings, several data elements are available.

- You can review the dE value for each color.
- You can review the raw xyY data for each color.
- You can review the provided CIE graph and color luminance bar chart of the measured gamut.
- You can generate a Quick Report.

Measuring Saturations

Overview

The Color Management module allows the user to adjust the primary and secondary colors of the display to match as closely as possible the reference gamut. Unfortunately, the color performance of consumer displays is not entirely linear. To see what this means, think of the gamut not just in terms of six primary and secondary colors and a white point, but also as many other colors falling not just on the edge of the color space, but distributed throughout at different levels of saturation, hue and intensity.

Saturation is just the distance from the white point. The reference gamut defines where a fully saturated color should fall relative to the white point on the gamut boundary. However, we can also think of the same color closer to the white point and thus less saturated. A perfectly linear display (assuming the HD gamut) would produce a fully saturated red at x0.640, y0.330. It would also produce a 50% saturated red, which is half way towards the white point at x0.476, y0.330. Unfortunately, they rarely do. A perfectly calibrated red at 100% saturation may measure correctly, while a 50% saturation red could show substantial errors. These errors, if large enough, are easily visible on regular program material, but remain completely unmeasured by the standard CIE chart, which ignores colors inside the gamut.

The Saturations tab within the Color Gamut module measures these errors. This tool is primarily diagnostic. The only way to actually correct colors inside the gamut are with a 3D LUT, such as the Lumagen. Even if you have a Lumagen, the Saturations module is useful primarily for initial diagnosis of the a problem and then subsequent validation that the problem has been fixed. Fixing the problem requires using the Advanced Auto-Calibrate option with a Lumagen. Some displays have linear color performance and do not need an LUT calibration. Nonetheless, this tool is useful for determining how well a CMS functions and whether it is advisable to calibrate your display at, say, the 75% saturation point of the gamut.

NOTE: You can measure saturations in either 25% or 20% increments. You can select between these in **Options**, **Gamut**.

To measure the saturation scale:

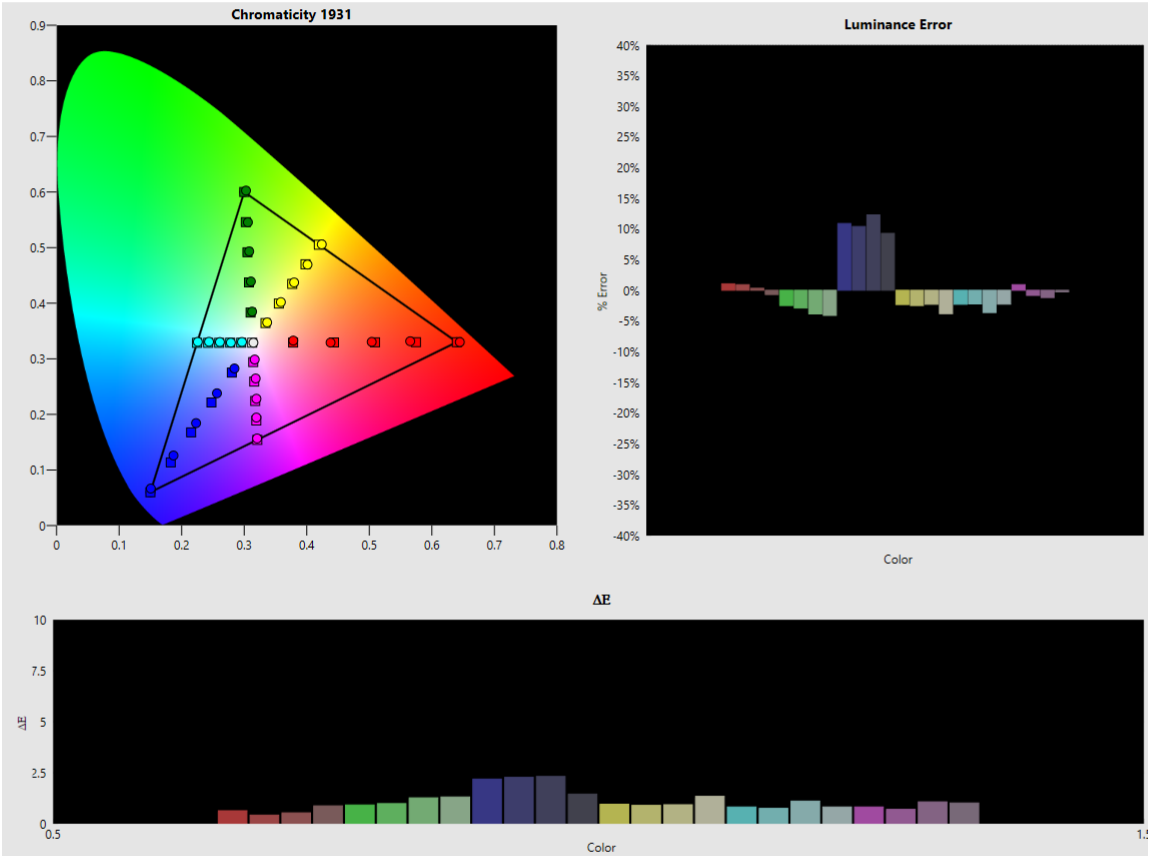
1. From the main navigation toolbar, click Pre or Post-Calibration Color Gamut.

   The **Color Gamut** module will appear.

2. The easiest way to measure Saturations is to just click **A** and measure all of the colors in this module, which will include the saturations.

3. Or, you can click the **Saturations** sub tab.

   The **Saturations** module will appear.



4 Display a 100% white test pattern if you have not done so already.

5 Click **A** to measure all. For other measurement options, refer to Taking Measurements in ChromaPure, p. 27.

6 Click the **Stop Measurements** button when the saturations have all been measured.

What do I look for?

The goal of these measurements is primarily diagnostic. What you want to see is that the measured saturation level for each color is a close to the targets on the CIE chart as possible and the dEs for the colors are as low as possible. Ideally, the colors will be as accurate inside the color space as they are at its outside boundary. The Saturations module will also help you to determine if perhaps you should calibrate your color using a saturation point less than 100% when using the standard Color Management module.

Using the ColorChecker

Overview

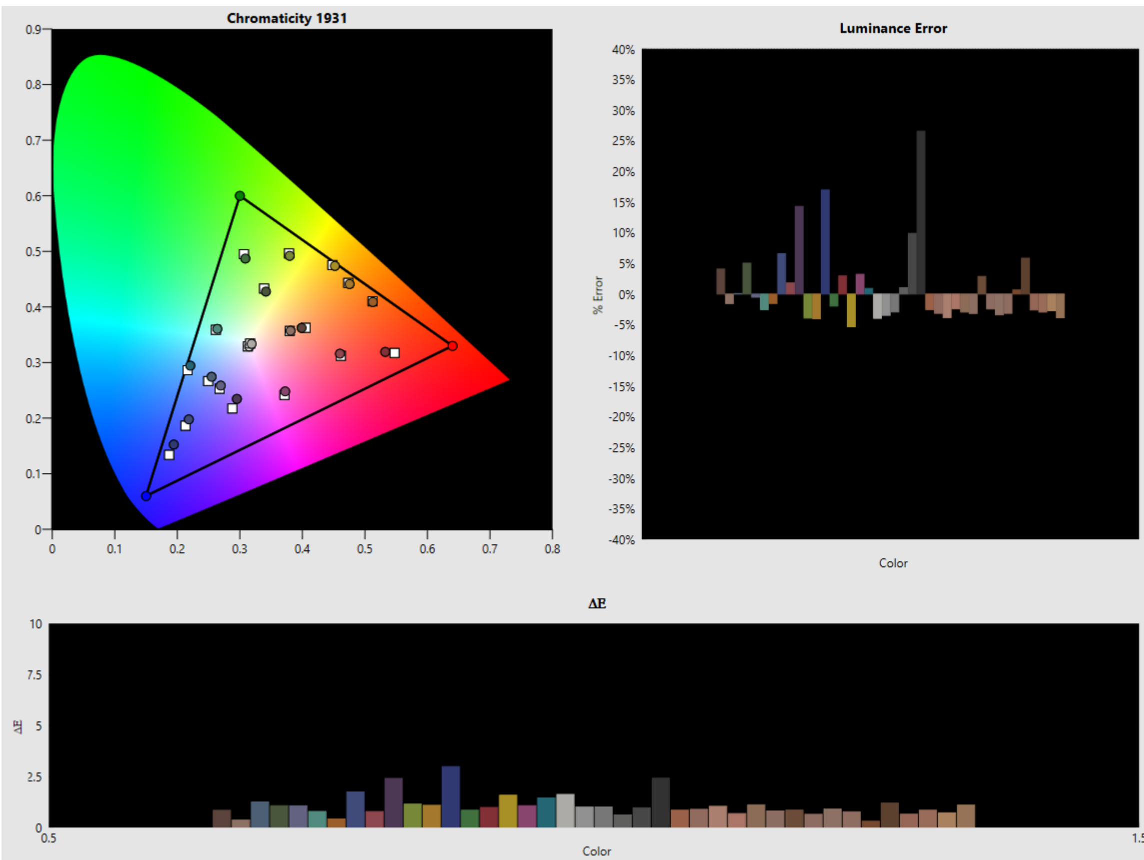
Within the Color Gamut module ChromaPure offers an illuminant D65 ColorChecker tool. The ColorChecker Color Rendition Chart was first introduced in a 1976 paper by McCamy, et al. It consists of a chart of 24 colors that mimic those of natural objects such as human skin, foliage, and flowers. It is a useful tool for diagnosing the color performance of displays. In 2006 X-Rite developed a ColorChecker Digital SG chart. This chart includes 140 patches, including the origi-nal 24 ColorChecker colors and 14 new skin tones. ChromaPure includes the skin tones only at the bottom of the standard ColorChecker. We add two additional skin tones that were devel-oped by us.

The ColorChecker is intended only as a diagnostic and reporting tool. It is not generally used as part of the regular display calibration process, except as a way of validating your adjustments.

To use the ColorChecker:

1 From the **Pre** or **Post-Calibration Color Gamut**, click the **ColorChecker** sub-tab.

The **ColorChecker** module will appear.



2 Display a 100% white test pattern if you have not done so already.

3 Click **A** to measure all. For other measurement options, refer to Taking Measurements in ChromaPure, p. 27.

4 Click the Stop Measurements button when the ColorChecker colors have all been measured.

TIP: If you are using an external signal generator or the ChromaPure Built-in signal generator, the necessary colors will be generated automatically. If you are using a calibration disc, then be sure to display the relevant color before attempting to measure.

Chapter 3: Calibration Procedures

What's Inside?

Setting White and Black Level

Overview

Properly setting black level (brightness) and white level (contrast or picture) of the display is a prerequisite for all other calibration adjustments. You should do this first.

To properly set black level (brightness):

1. Display a black pluge pattern that contains video information just above and below vid-eo black against a fully black background.
2. Lower the brightness control until the just-above-black bar fades into the background and becomes invisible.
3. Slowly raise the brightness control until the just-above-black bar reappears and be-comes clearly visible.

The correct setting for brightness is when the just-below-black level is invisible and the just-above-black is visible. If just-below-black is visible, then brightness is set too high. If just-above-black is invisible, then brightness is set too low.

NOTE: Video black is digital 16 on a 0-255 scale. Video white is 235 on the same scale. Everyone agrees that information below 16 should be invisible and that everything between 16-235 should be visible. There is some controversy as to whether and to what extent we should be concerned about above white material (236-255).

To properly set white level (contrast):

1. 1.Display a white pluge test pattern that contains video information just-below-white and just-above-white against a fully white background.
2. 2.Start with the contrast control set to its maximum. Slowly lower the control until the just-above-white information is visible.

The correct white level setting is that setting at which 3 conditions are met:

- The level of 100% white is consistent with the display type (see below). Use the Raw Data Module to check luminance at 100% white.
- The just-below-white bar and just-above-white bar are clearly visible.
- The color of full white is neutral. Use the White Balance tool to check the color of white. For more information about the White Balance tool, refer to Setting White Balance, p. 36.

Light Output Targets for Various Display Types

- CRT/Plasma/LCD Flat Panel/OLED/Rear Projector: 35 fL (120 cd/m2)
- Digital front projector: 14 fL (48 cd/m2)

Just set the contrast at the recommended limit (or a little higher) so long as the other two criteria are also both met. Your display may not be able to achieve the minimum recommended light output. This is fine. Just get as close as you can. However, going much over the recommended value is not recommended. A higher setting may lead to eye strain, excessive image noise, and lessened operating life of the display.

TIP: The brightness and contrast settings are usually interactive, so you should go back and forth between them to ensure that both parameters are correctly set.

Setting White Balance

Overview

Setting the white balance is arguably the most important step in calibration. Getting the color of white correct affects all viewing material, even black-and-white content. The correct white balance is achieved when white contains equal amounts of red, green, and blue of the refer-ence gamut. As it turns out, all of the gamuts commonly used (SMPTE-C, Rec. 709, and EBU) use the same white point, x0.3127, y0.329.

There are two types of white balance correction, 2-point and multipoint. The 2-point process is described below. In the multipoint process, supported by some displays and video processors, you can adjust the grayscale at each point individually. This is provided in either 10-point (10%) or 20-point (5%) increments.

To set white balance:

1. Click the **White Balance** module icon on the main page.

   The **White Balance** module will appear.

2. Display a 100% white test pattern.

3. Click **Measure**.
4. Display a 80% gray test pattern, and click **Measure**.

   The application will return information for:

   - dE
   - Raw xyY data
   - CCT
   - Gamma
   - RGB balance

This initial measurement provides a snapshot of the white balance at that video level.

5. Click **Continuous**. The application will show the data listed above as it changes in real time.
6. Adjust your display's white balance controls to get the RGB balance as close to 100% for red, green, and blue as possible. Between 98% and 102% or no more than 2 dE is a good goal.
7. When finished, click **Stop**.
8. Display a 20% gray test pattern.
9. Repeat steps 4-7 as necessary.

TIP: Setting white balance is a reiterative process. Whenever you adjust the white balance at the low end of the grayscale you must then recheck the white balance at the high end again, and vice-versa. This is necessary because changes in one are likely to effect the response in the other. The goal is to get a good white balance at both ends of the grayscale at the same time.

There is no standard industry-wide terminology for white balance controls.

You may see RGB Contrast/Brightness, RGB Gain/Bias, RGB Gain/Offset, RGB Drives/Cuts. They all mean the same thing.

Bright end of the grayscale

- Contrast
- Gains
- Drives

Dark end of the grayscale

- Brightness
- Biases
- Offsets
- Cuts

The display's white balance controls may be easily accessible in the user menu, or they may be hidden in a special service menu accessible only through a unique key combination on the remote.

In unusual cases the default white point will not be suitable for your display.

Metameric Failure

Overview

With some displays, especially wide gamut Quantum Dot LED displays, the observed white point may vary from the measured white point. In other words, even though white measures neutral white it can visually appear with red, blue, or green bias.

The only way to fix this is to use an optical comparator as a corrective. Use the following technique to address the problem.

1. Display a 50% full field gray test pattern on your computer screen.
2. Using the most accurate instrument you have and the monitor's own white balance controls, calibrate that white point to as close to 0.3127, 0.329 as possible. Once you are satisfied with your efforts, the PC screen becomes your optical comparator.
3. Display a 50% gray test pattern on the TV to be calibrated. In the vast majority of cases if the TV has already been calibrated the two screens should look the same. If they don't then you have a metamerism problem.
4. If you see a problem, use the TV's white balance controls until the TV's 50% white point visually matches the computer screen's 50% white point.
5. Measure the TV's white point. It will now be different from 0.3127, 0.329. Make a note of the measured value.
6. Open the Gamut tab in the Options module and apply this custom white point to the gamut.

The result should be that when you measure the TV, you get 100%, 100%, 100% RGB values for this custom color instead of the default white point.

Using Color Management

Overview

Use the Color Management module if the display includes a color management system (CMS) that provides control over the hue, saturation, and lightness of the primary and secondary colors. You can also select the desired color space in which to work. Select the color space that best corresponds to the human interface in the CMS controls. For example,

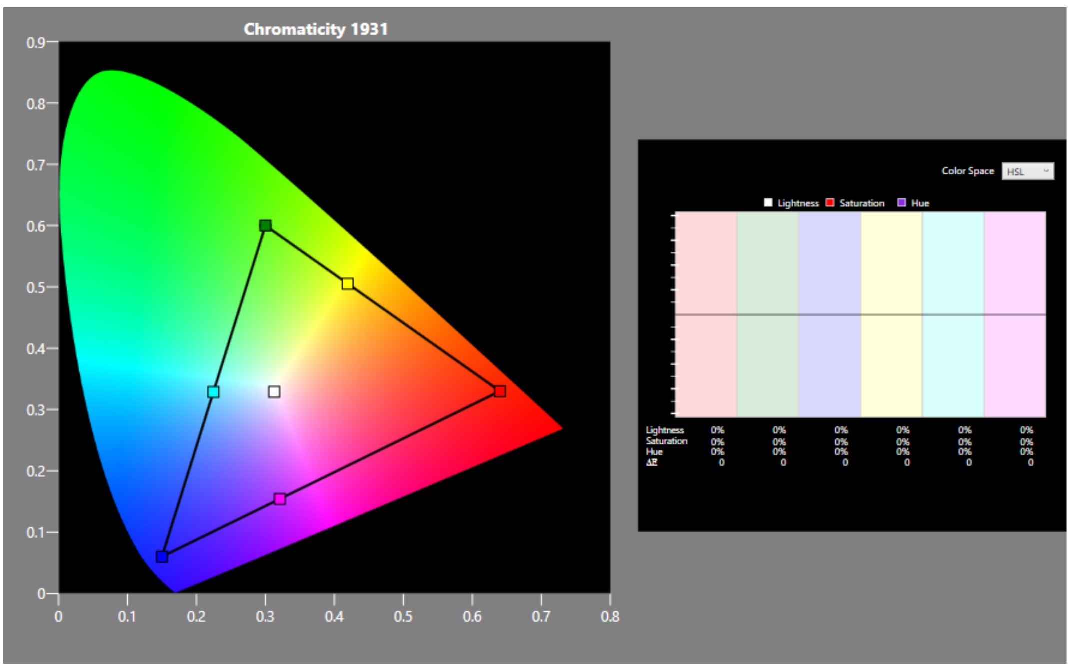
- Select HSL for CMS's that rely on these adjustment parameters, such as the JVC LCoS projectors.

- Select RGB for CMS's that rely on these adjustment parameters, such as the Samsung flat panels and the Lumagen Radiance external video processors.
- Select xyY for CMS's that rely on these adjustment parameters, such as the DVDO Duo external video processor.

To use Color Management:

1. Select the desired Reference Gamut in **Options**.
2. Select the desired test pattern intensity from the **Initial Setup** module.
3. Click the **Color Management** icon on the main interface.

The **Color Management** module will appear.



4. 4.Take an initial measurements of white, red, green, blue, yellow, cyan, and magenta to obtain a baseline reading.

   The following data will appear:

   - Percentage error in each of the three axes of the selected color space for each primary and secondary color.
   - The dE error for each primary and secondary color.
   - The raw xy data displayed on a CIE chart.
5. Display a test pattern for the target color.
6. Select the radio button for that same color.
7. Click **C** to measure in the continuous mode.

ChromaPure will measure changes in the selected color space in real time.

8 Adjust your display's CMS controls to bring the error of the selected color to as close to zero as possible. It is useful to pay close attention to the dE value shown below the percentage error bars to determine what mix of errors in the selected color space offers the most accurate color.

9 Click **Stop**.

10 Repeat steps 4-7 for whatever color or colors require correcting.

Calibrating to Targets within the Gamut

Overview

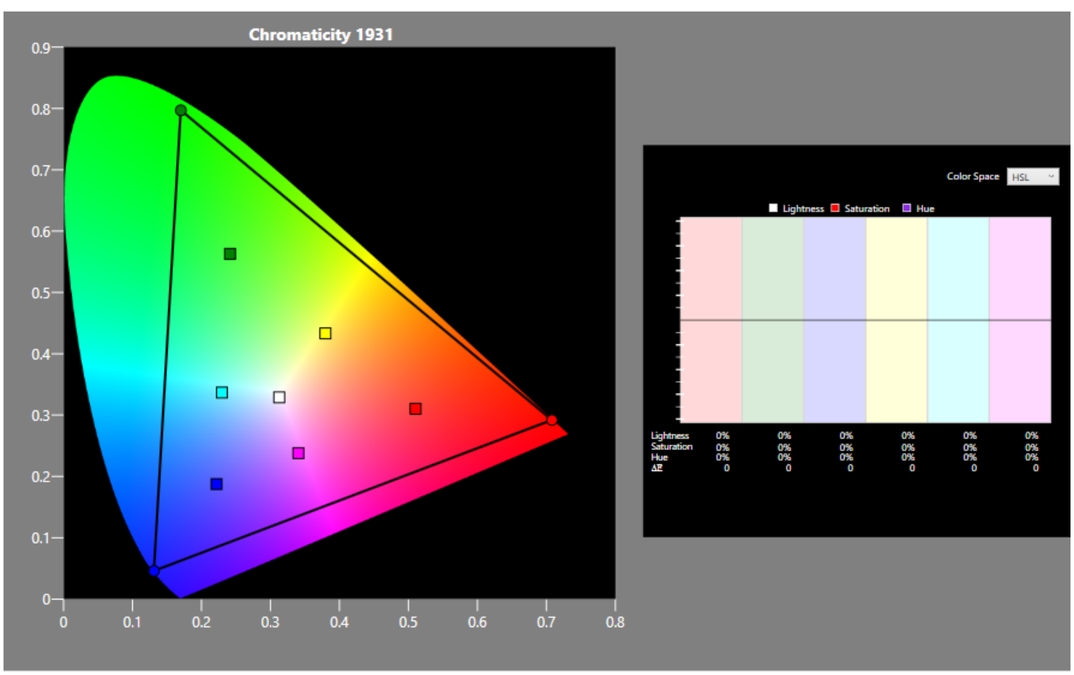
For many displays, the most accurate measurement of color performance is provided inside the color space instead of on the gamut boundary. For this reason, it is useful to offer the option to calibrate to different levels of saturation other than 100%. Different levels of saturation are simply points inside the gamut closer to the white point. For example, 75% saturation is 75% of the distance between white and the gamut's reference color.

To calibrate to targets within the gamut:

1 1.Click the **Module Options** button in the **Color Management** module.

2 2.In the **Saturation** drop-down select a value less than 100%, which is the default. 75% and 50% are provided.

Additional color points will appear inside the gamut. (*50% of Rec. 2020 shown*)



3 Calibrate normally as described above, except that the reference colors are now inside the gamut.

Correcting Color Decoder Errors (Color and Tint)

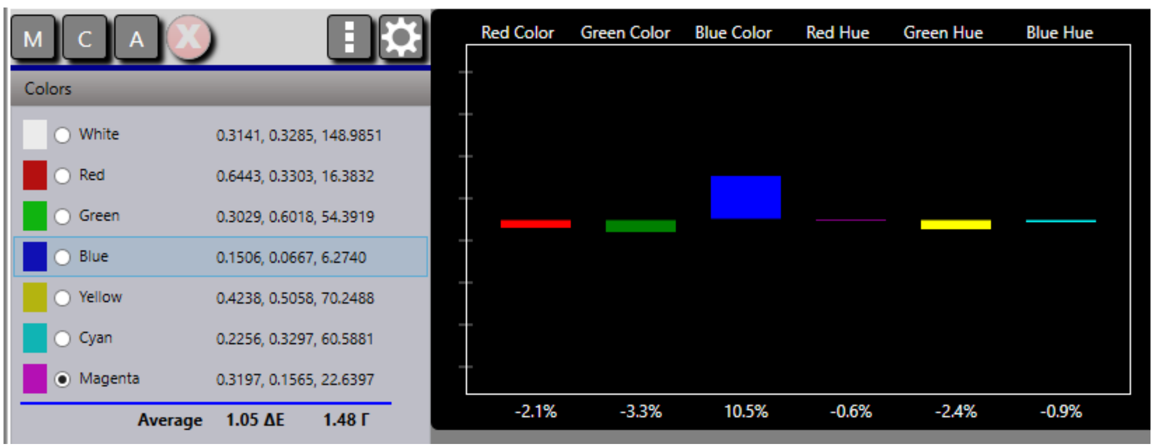
Overview

Use the Color/Tint module when your display lacks a full-featured CMS. Some displays have color decoding controls that allow you to independently adjust the brightness of each primary color and the hue of each secondary color. Most displays, however, only have a universal Color and Tint (or Hue) control.

To adjust a display's color decoding performance:

1 Click **Color/Tint** on the main navigation tool bar.

The **Color/Tint** module will appear.



2 Take an initial measurement of White, Red, Green, Blue, Yellow, Cyan, and Magenta to get a baseline.

The percentage error in RGB Color and RGB Hue will appear on the graph. RGB Color measures the percentage error of the luminance of each primary color. RGB Hue measures the percentage hue error of each secondary color (magenta-red hue, yellow-green hue, and cyan-blue hue).

3 Display a red test pattern.

4 Select the Red radio button.

5 Click **C** to measure in continuous mode.

ChromaPure will measure changes to the to the luminance of red in real time.

6 Adjust the color decoding control or the main color control to achieve the smallest percentage error as possible.

7 Click **Stop**.

8 Repeat 4-7 for the other two primary colors.

9 Display a magenta test pattern.

10 Click the **Magenta** radio button.

11 Click **C** to measure in continuous mode.

ChromaPure will measure changes to the red hue in real time.

12 Adjust the main tint or hue control on the display to achieve the smallest percentage error as possible. Repeat 9-12 for the remaining secondary colors.

What's the difference between Color Decoding and Color Management?

Both modules measure the luminance of the primary colors and the hue of the secondary colors. However, there are a couple of important differences between them.

The **Color Management** module uses lightness to display the percentage color luminance error, whereas the Color Decoding module uses relative luminance to display the percentage color luminance error. For more information on the difference between luminance and lightness, refer to Lightness and Luminance, p. 71.

Depending on the selected color space, the **Color Management** module gives the calibrator three axes of adjustment

- Hue, Saturation, and Lightness (HSL)
- Red, Green, and Blue (RGB)
- x, y, and Y (xyY) for each of the six primary and secondary colors.

The **Color/Tint** module offers only one axis of adjustment for the RGB, the primary colors (color luminance) and one axis of adjustment for YCM, the secondary colors (hue). These adjustments are the only ones offered because these are where the overwhelming majority of color decoding errors occur—luminance of the primary colors and hue of the secondary colors.

Measuring and Adjusting Gamma

Overview

All displays have gamma, which numerically reflects the relationship between the intensity of signal input relative to the intensity of measured output. This relationship between input and output is not linear. There are two reasons for this.

- First, the display device traditionally used for image reproduction and video production (the CRT), has a voltage input to signal output relationship that is itself non-linear.
- Second, and quite coincidentally, human perception is nonlinear as well in approximately the inverse of CRTs. Thus, all display devices must exhibit gamma to accommodate both of these phenomenon. Gamma can be displayed as a non-linear curve on a graph plotting

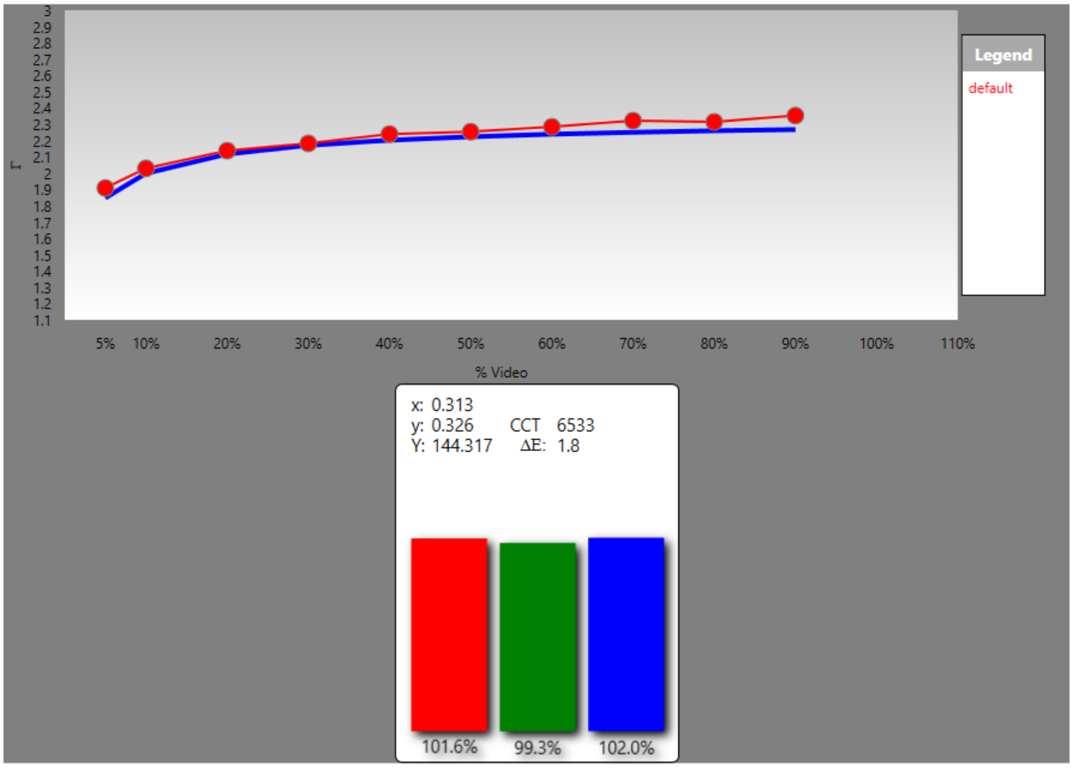
input and output or as a more or less horizontal line on a graph indicating the gamma function at each video level.

By default, ChromaPure documents gamma in the latter way. Ideally, you would want a line somewhere in the 2.1-2.4 range. A gamma response that is too high will offer great image depth and deep blacks, but you will lose shadow detail and the image may appear "contrasty." A gamma function that is too low will provide great shadow detail, but contrast will suffer and the image may lack depth.

To measure and adjust gamma:

1 Click the **Gamma** icon on the main navigation tool bar.

The **Gamma** module will appear.



2 Click the **Application Settings** icon and select the desired gamma if you have not done so already. The selection is not applied until the **Application Settings** panel is closed.

3 Display a 100% video pattern.

4 Click **M** to measure.

ChromaPure will take a measurement and then automatically advance to the next level. There are a variety of ways to continue measuring. For more information, refer to Taking Measurements in ChromaPure, p. 27.

The application will take a measurement, return a gamma value for that level, and then automatically advance to the next level.

5 Continue until you have finished measuring all video levels.

6 The **Gamma** module also contains a RGB graph like the one in the **White Balance** module. After you make adjustments to the gamma response, you will almost certainly need to readjust white balance. You can use this tool for this purpose and never leave the **Gamma** module.

NOTE: Only the values above 0% and below 100% stimulus have gamma. 100% is only used as a reference from which gamma at the other levels of stimulus are calculated. 0% is not measured at all.

Displays generally offer one of two ways to adjust gamma.

- Select from various gamma presets.
- Adjust the luminance output at each video level.

You can use either of the these methods to adjust your gamma response. It all depends on what controls your display offers. If you put the **Gamma** module into continuous mode, you can see changes in real time to the gamma response at any level of stimulus. When the measurements are complete, you will have gamma values at each level of stimulus and an average gamma value.

Module Options

The **Gamma** module, like the **Grayscale** modules, allows the user to select between 12 and 21 points of measurement. It also allows the user to select the desired dynamic range with 100% (default), 104%, and 109% as available options.

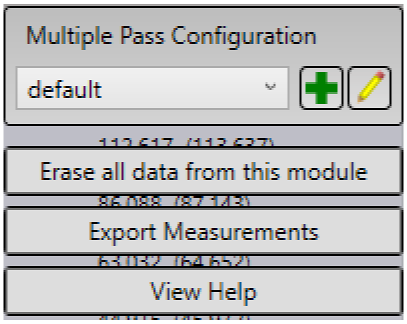
Recording Multiple Gamma Runs

Overview

It may sometimes be useful to measurement several gamma runs and plot them all on a single graph for comparison purposes. ChromaPure 3 offers this ability. For example, your display may have several gamma presets. You can use this tool to document the actual gamma response of each of these presets, which may be very different from their nominal designation.

To record multiple gamma runs:

1 Open the **Module Options** panel.



You'll notice the label *default* under **Multiple Pass Configuration**. You will want to change this.

2 Click the pencil icon to enter editing mode.

3 Change default to whatever gamma designation you want to measure first. For example, your display might have a 1.8 selection, so you would type 1.8 replacing default.

The pencil icon will become a green check mark.

4 Click the green check mark icon to accept the new label.

The new label will appear on the legend at the right end of the gamma graph.

5 Measure the entire gamma response.

To measure another gamma preset, simply repeat these steps as many times as necessary. Each gamma run will appear color coded on the gamma graph along with the appropriate label in the legend.

If you wish to run a Quick Report on this, then measure no more than three gamma responses at a time. You can run multiple reports if you wish to show more than three gamma responses. Alternatively, you could simply take a screen shot of the gamma graph in the **Gamma** module without running a report. This graph will display up to eight color-coded simultaneous gamma responses.

Measuring Contrast

Overview

Contrast—the difference between the luminance of the display's black level and its white level—is one of the most important indicators of image quality. There are two types of contrast.

- **Sequential Contrast:** Otherwise known as on/off contrast, this indicates the difference between the black level of the display and its white level when each is measured one after the other. Use a 0% and then a 100% white test pattern for this.
- **Simultaneous Contrast:** This indicates the difference between black and 100% white when both are displayed at the same time. Use a checkerboard test pattern for this.

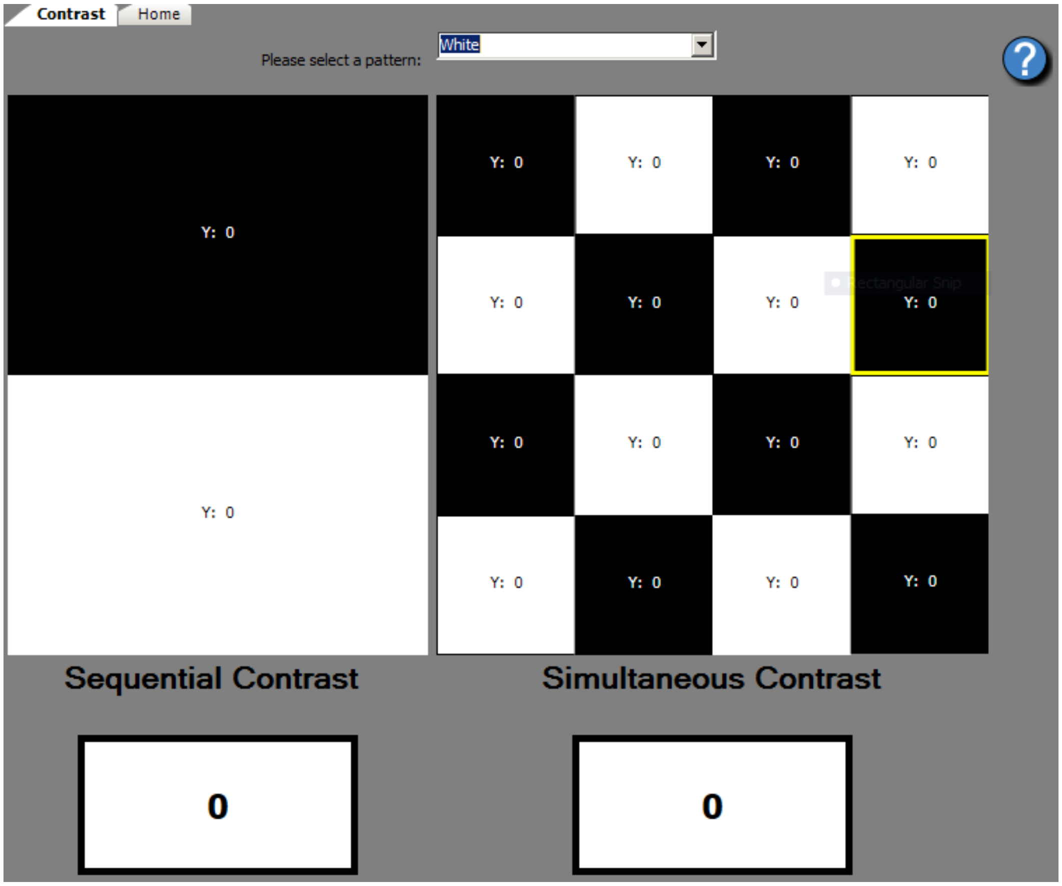
Because the white squares will affect the black squares on a checkerboard pattern, simultaneous contrast is always considerably lower than sequential contrast.

You may want to take contrast readings both before and after the calibration. When taking a post-calibration reading, ensure that you have already properly set the display's black level and white level. For more information about this, refer to Setting White and Black Level, p. 35.

To measure sequential contrast:

1 Click **Contrast** on the main interface.

The **Contrast** module will appear.



2 From the **Please select a test pattern** drop-down, select **Black**.

If you are using a signal generator, a black test pattern will appear. Otherwise, select a black test pattern from a disc.

3 Click inside the large black square on the left.

A luminance value will appear in either fL or cd/m2. This is your display's black level.

4 From the **Please select a test pattern** drop-down, select White.

If you are using a signal generator, a white test pattern will appear. Otherwise, select a white test pattern from a disc.

A value will appear in large numbers below. This is the Sequential Contrast.

To measure simultaneous contrast:

1. From the **Please select a test pattern** drop-down, select **Checkerboard**.

   If you are using a signal generator, a checkerboard test pattern will appear. Otherwise, select a checkerboard test pattern from a disc.

2. Place the meter opposite one of the black squares.

3. Click the black square.

   A luminance value will appear in either fL or cd/m2. This that square's black level.

4. Place the meter opposite one of the white squares.

5. Click the white square.

   A luminance value will appear in either fL or cd/m2. This that square's white level.

6. You can repeat this sequence as many times as you wish, measuring both white and black squares, as long as you have measured at least one black and one white square. Any additional measurements will be averaged.

   A value will appear in large numbers below. This is the Simultaneous Contrast.

Using Auto-Calibrate

Overview

ChromaPure offers an auto calibration tool as an optional add-on to the main program. ChromaPure Standard users may purchase this add-on. For ChromaPure Professional users Auto-Calibrate is provided free of charge. This tool only works in conjunction with either the DVDO Duo or Lumagen Radiance family of external video processors. It allows the user to set some basic options and then just click a button and the system will fully calibrate the display and even generate a comprehensive calibration report without any additional user input. Calibrations take from 5-10 minutes to complete depending on the speed of the color analyzer you use.

If you are a Lumagen user, you can also add an additional advanced auto-calibrate feature. This allows you to calibrate not just six colors along the gamut boundary, but 124/728/4912 colors spaced evenly throughout the color space. Using this feature takes an additional time (depending on the number of colors in the measurement sequence) to complete and results in studio-quality color performance.

Before running Auto-calibrate

Getting good results from auto-calibrate is largely dependent upon the starting point. Follow these tips to get the best out of the auto-calibrate session.

Ensure that Measurement Smoothing is turned off in Application Settings. For more information, refer to Measurement Smoothing, p. 22.

Select the most accurate Picture preset on your display. You can take a set of **Pre-Calibration Grayscale** and **Color Gamut measurements** to determine this. The smaller the errors when you begin, the better the results when you finish. For more information, refer to Taking Pre-calibration Grayscale Measurements, p. 28 and Taking Pre-calibration Color Gamut Measurements, p. 29.

TIP: Select a Picture preset that does NOT include either undersaturated colors or colors whose luminance is too low. If necessary, you may be able to raise color luminance by raising the main color control slightly. Also, if the gamma response falls off dramatically at the high end, that generally means that the contrast is set too high. In such cases, lower the contrast control on the display until the gamma response at 90% is at least 1.6.

Running Auto-calibrate

To use Auto-Calibrate:

1. Ensure that Auto-Calibrate is enabled. This requires a specific setting in the license file. If your license does not support Auto-Calibrate, then the **Auto-Calibrate** button will be grayed out. Contact ChromaPure support to purchase this option.
2. Select and initialize the desired meter.
3. If running Lumagen Radiance Advanced auto-cal, then ensure that the **Color Intensity** selector on the Initial Setup module is set to 100%. If running auto-calibration with the

TIP: If you wish to use meter correction, ensure that you do this now before the auto-calibrate session begins. For more information about meter correction, refer to Creating A Meter Correction, p. 26.

DVDO Duo, make sure that **Color Intensity** is set to 75%.

4. If you have not already done so, setup the desired Calibration Device. Auto-Calibrate currently supports either the DVDO Duo or the Lumagen family of processors.
5. Manually adjust the brightness, contrast, and sharpness of your display.
6. Manually calibrate white balance at 100% video using the display's white balance controls (not the video Processor's controls).
7. On the main navigation bar, click the **Auto-Calibrate** button.

   The **Auto-Calibration** module will appear.
8. Select the desired options in the **Auto-Calibration Setup** window, and then click **Next**.

   The colors panel will populate with colors reflecting your choice in the just completed step.

9 To start auto-calibration click the **Measure All** button on the module toolbar.

The process will begin and display activity in the window. You can cancel the session at any time. When it has completed, you can generate a calibration report by clicking the Quick Re-port icon on the module toolbar.

Using Video Processor Manual Control

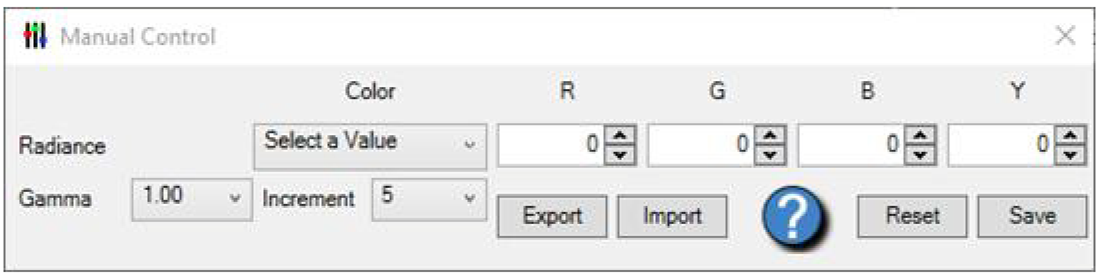
Overview

The DVDO Duo and Lumagen Radiance video processors offer built-in calibration controls. Use ChromaPure's Video Processor Manual Control Panel to use these controls without resorting to either processor's remote control and on-screen display.

To use the Video Processor Manual Control Panel:

1. Ensure that the Lumagen or Duo has been setup and configured.
2. Click **Generator Ctrl** from the main interface.

   The **Video Processor Control Panel** will appear.



3. Select a color or grayscale point to adjust.
4. Select an increment size for the adjustment.
5. Adjust R, G, B or Y up or down while measuring the desired color patch in continuous mode (xyY for the DVDO Duo).

This panel also provides the following controls:

- **Export:** Export the adjustments as a XML file.
- **Import:** Subsequently import the adjustments previously exported to an XML file.
- **Help:** Open the Help file.
- **Reset:** Reset all of the adjustments to their defaults.
- **Save:** Save the adjustments made to the active Lumagen configuration.

Chapter 4: Post-Calibration Procedures

What's Inside?

Taking Post-Calibration Grayscale Measurements

Overview

Taking measurements in the Post-Calibration Grayscale module works just like the Pre-Calibration Grayscale module. Its only function is to measure the results obtained from your calibration session for reporting purposes. You can then compare the pre and post measurements in the calibration report. For more information about taking a grayscale measurement, refer to Taking Pre-calibration Grayscale Measurements, p. 28.

If you see any problems in the readings, then return to the **White Balance** and/or **Gamma** modules and make further adjustments.

NOTE: You must take Pre and Post-Calibration Grayscale measurements to obtain the necessary data for reporting.

Taking Post-Calibration Color Gamut Measurements

Overview

Taking measurements in the **Post-Calibration Color Gamut** module works just like the P**re-Calibration Color Gamut** module. Its only function is to measure the results obtained from your calibration session for reporting purposes. You can then compare the pre and post measurements in the calibration report. For more information about taking a color gamut measurement, refer to Taking Pre-calibration Color Gamut Measurements, p. 29.

If you see any problems in the readings, then return to the **Color Management** and/or **Color/Tint** modules and make further adjustments.

NOTE: You must take **Pre/Post-Calibration Color Gamut** measurements to obtain the necessary data for reporting.

Running a Calibration Report

Overview

Once you have completed your calibration session, it is useful to have a permanent record of the results. ChromaPure provides four calibration reports

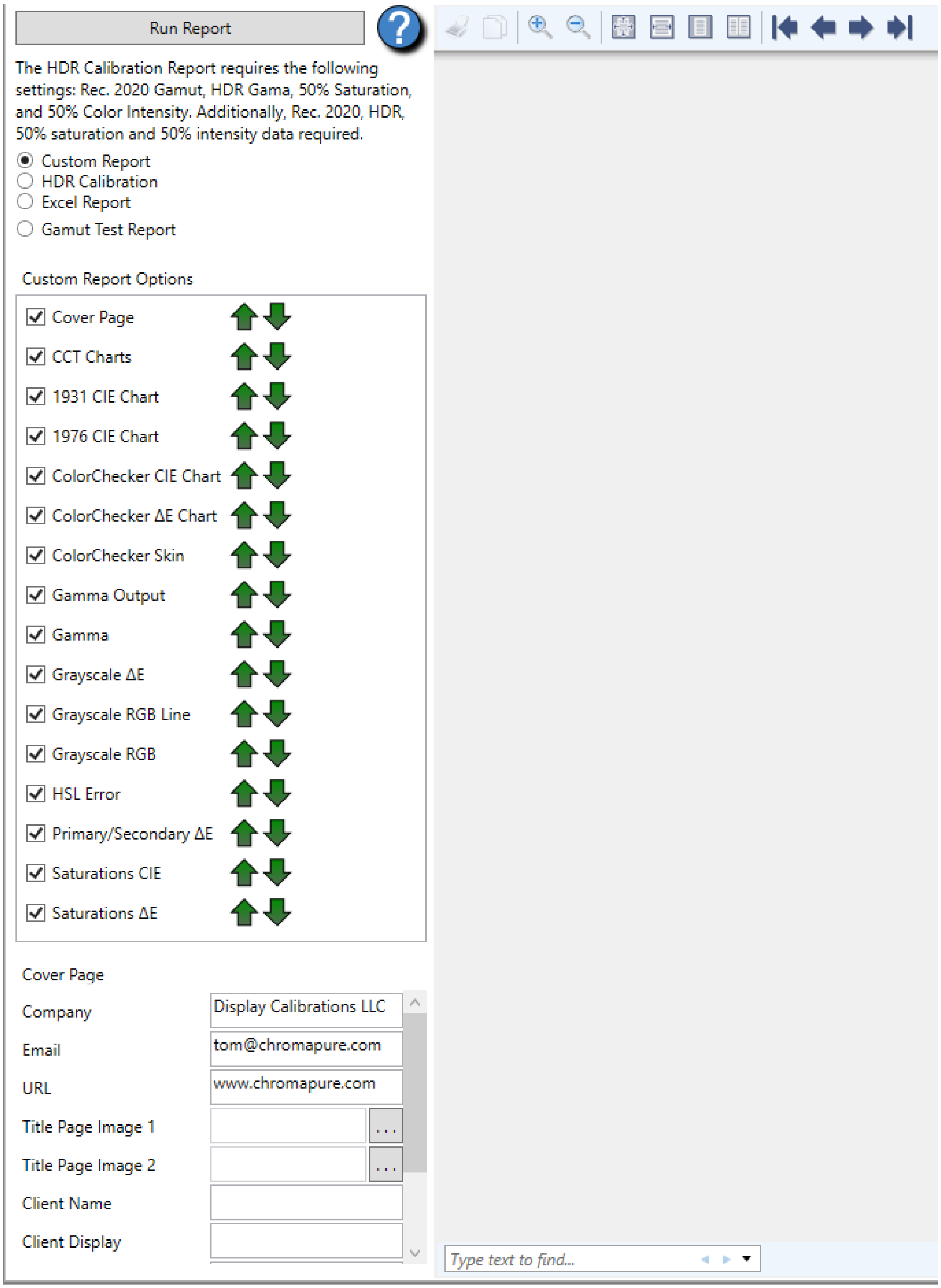
- A multi-page custom report
- A Gamut Test report
- An HDR Report
- A comprehensive report in Microsoft Excel format.

The reports contain both raw xyY data and charts and graphs displaying the pre and post calibration performance of your display.

To run a calibration report:

1 Click the **Reports** icon on the main interface.

The **Calibration Report** page will appear.



2 Click the desired report type.

3 Click **Run Report**.

A printable calibration report will appear. You can then export the report pdf or XPS to make it sharable with others.

Exporting report data

All export features are handled by the report window's **Print** feature.

1. To export a report to a sharable electronic file, such as pdf or XPS, click the Print icon on the report toolbar.
2. To print to XPS, select Microsoft XPS Document writer as your printer, and then click OK. All versions of Windows include the XPS writer.

   You will be prompted for a document name and location.
3. Provide a name and location, and then click Save.
4. To export the report in pdf format, follow the same steps as above, except choose pdf as your printer. A pdf printer is included with the full version of Adobe Acrobat and Windows 10. If you have neither, then there are many free pdf printers you can down-load from the Internet and install for free.

Gamut Test Report

Overview

Unlike the other reports that rely upon measurements already taken during the calibration process, the Gamut Test Report requires taking an independent sweep of measurements. The 215 measurements taken sample the entire gamut and then generates a dE report showing the accuracy of the display (the dE results assume a 2.22 gamma). You can use the results on the report to determine whether a full LUT calibration of the display is warranted.

Running in its default mode, this report uses the active signal generator (external or Built-in) to produce the needed test patterns and is entirely automatic. Thus, running this report requires an active signal generator.

Customizing the calibration report

Along the left side of the report window you'll notice a check box and green up/down arrows next to names of each report page. To generate a specific report page, ensure that the check-box next to that page is checked. To adjust the order of the pages shown, click the up/down arrows.

You can also customize the content on the report's cover page. Just type the desired information in the provided text boxes. To add images to the cover page, simply click the browse but-tons, and select the desired image. Acceptable image formats include JPG and PNG.

Interpreting the Calibration Report

The calibration report summarizes data gathered from the calibration session. It includes several different sections, each showing before and after performance.

- **Grayscale dE:** This page shows raw xy data, dE, and CCT for the grayscale. It also graphs the be-fore/after dE performance. You should aim for grayscale results in which dE is no larger than 2.0 (CIELAB, CIE94, or CIE2000) or 3.0 (CIELUV). You can select your prefer-ence for which dE color difference model you wish to use.
- **CCT Chart:** This page again shows grayscale performance, but this time using Correlated Color Temperature (CCT) as the standard. A neutral shade of white is 6505k. Lower than that is too red and higher than that is too blue. CCT is a deprecated metric because the measurement is imprecise. This is because CIE never endorsed a specific method for cal-culating CCT (there are several) and, more importantly, it ignores the contribution of green. You can have two very different shades of white that share the same color temper-ature. For this reason, dE, RGB balance, or even the raw xy coordinates are all better measures of the color of white.
- **RGB Bar Chart:** This page shows the same grayscale data as above, but breaks the results out by the contributions of red, green, and blue. A perfectly neutral white for the selected gamut will have 100% values for all three primary colors. Aim for no more than ± 4% RGB error.
- **RGB Line Chart:** This shows the same data as the RGB bar chart, but in line format.
- **Primary/Secondary dE:** This page shows the dE performance of the primary/secondary colors relative to the target gamut. You should aim for a post-calibration result in which the primary/secondary colors have a dE of no more than 1.5 (CIE94 and CIE2000), 4.0 (CIELAB), or 5.0 (CIELUV). Unless your display includes an effective color management system, you will unlikely be able to achieve results this good.
- **1931 CIE Chart:** This page shows a subset of the same information as above plotted on a familiar CIE chart. These charts plot saturation and hue errors only. The report includes the 1931 xy version, which is less perceptually uniform than the 1976 u'v' chart but more familiar to most users.
- **1976 CIE Chart:** This shows the same data as the 1931 CIE chart, but uses the more per-ceptually uniform u'v' chromaticity coordinates.
- **HSL Error:** This page shows the same information as above, but breaks out the contribu-tions to the before/ after color errors in terms of percentage errors in hue, saturation, and lightness. You should aim for no more than ± 2% error in any component. Unless your display includes an effective color management system, you will unlikely be able to achieve results this good.
- **Gamma:** This page plots luminance performance of the display. This includes gamma, which is the display's ability to properly increase signal output as signal input increases. The relationship between them is summarized mathematically and referred to a gamma. You should aim for a gamma value that is in the 2.1-2.4 range. This page also shows the

contrast and white lev-el/black level performance of the display. For comfortable viewing you should aim for a white level of 30-40 ft-L for flat panels, and 12-16 ft-L for front projection. The black level should be as low as possible without losing shadow detail. The SMPTE reference projector provides an on/off contrast ratio of no lower than 4000:1.

- **Gamma Output:** This page shows the same data as the Gamma page, but displays the gamma data on a chart that uses percentage output/percentage input as the xy axes.
- **ColorChecker CIE Chart:** This page shows the ColorChecker data plotted on a standard 1931 CIE chart.
- **ColorChecker dE Chart:** This page displays the dE values of the ColorChecker colors.
- **ColorChecker Skin:** This page shows the dE values of the ColorChecker skin tone colors.
- **Saturations CIE:** This page shows the Saturations data plotted on a standard 1931 CIE chart.
- **Saturations dE:** This page displays the dE values of the Saturations colors.

Quick Reports

Overview

In addition to the standard reports you can run on your calibration session, ChromaPure also includes Quick Reports within the application. These are available in the Pre/Post-Calibration Grayscale, Pre/Post-Calibration Color Gamut, and Gamma modules. They offer a simple and fast method for obtaining a quick snapshot of the pre and post-calibration data.

To run a Quick Report:

1. From within the **Pre/Post-Calibration Grayscale**, **Pre/Post Color Gamut**, or **Gamma** modules, click the **Quick Report** button.

   A **Quick Report** will be generated from the data in the module.

2. You can export the report as an PDF or XPS or take a screenshot and save as an image.

Chapter 5: Calibration Tools

What's Inside?

Sharing Data

When you have completed your calibration, you may wish to share the data with others.

- Take a screenshot of any graph or page within ChromaPure and save as an image file. For more information about taking a screenshot in Windows, refer to Taking Screenshots, p. 66.
- Export the entire calibration to a session file. These files have a calx extension and can be opened by any other ChromaPure user.
- Export xyY data from several modules in CSV format. This raw data can be opened by Excel.
- Generate a comprehensive calibration report. This can be printed and shared as hard copy or converted to electronic file and then e-mailed or posted online.

Importing and Exporting Calibration Data

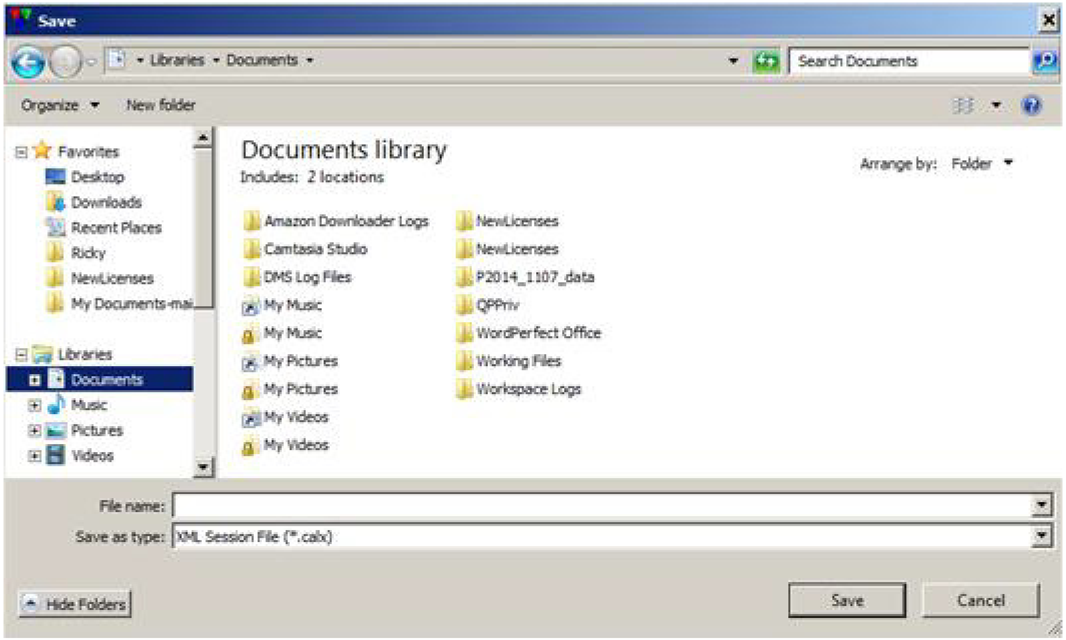
Overview

It is important that you are able to export the results of a calibration session so you can open the data in ChromaPure later or share with other ChromaPure users. It is also useful to export raw calibration data to use with other data analysis tools or to share with those who are not ChromaPure users.

To export a calibration session:

1 From the main interface page, click **Save Session**.

A **Save** window will appear.



2 Select XML Session File from the Save as type box.

3 Type a desired name for the file in the File name box.

4 Select a desired location in the Save in box.

5 Click **Save**.

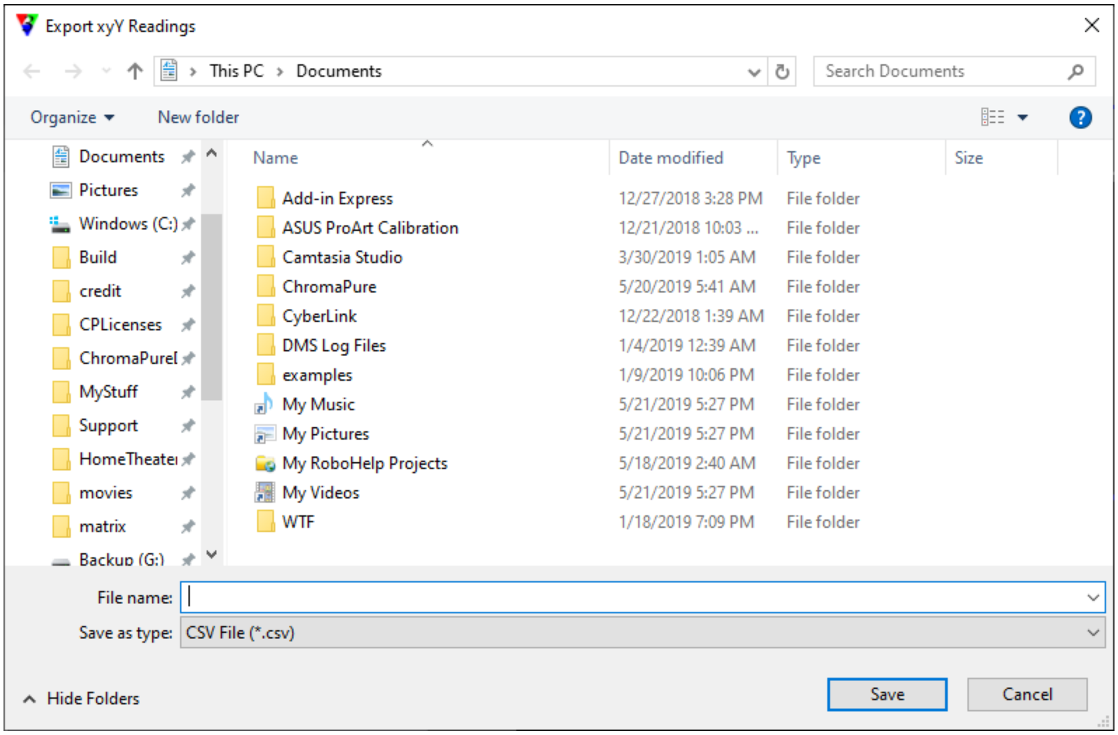
A file with the specified name will save in the specified location. It will have a .calx extension. You or any other ChromaPure user can subsequently open this file, view the data and associated charts, and run a report on the data. This file includes all of the basic calibration data.

NOTE: ChromaPure includes a fail-safe feature in case you forget to save the calibration data. Whenever you attempt to exit the program, you will be prompted to save a calibration file first. Also, if for whatever reason, the program shuts down abnormally, when you re-start, you will be prompted to restore the calibration data from the previous session.

To export calibration data as CSV:

1 From within the module whose data you wish to export, click the **Module Options** button, and then select **Export Measurements**.

An **Export xyY Readings** window will appear.



2 Type a desired name for the file in the **File name** box.

3 Select a desired location in the main window.

4 Click **Save**.

A file with the specified name will save in the specified location. It will have a csv extension. You can open this file format in Excel for data analysis. The file includes raw xyY data from the Pre/ Post Grayscale and Color Gamut modules. All calibration information can be derived from these values.

To import a session file:

1 From the main interface page, select **Load Session**.

A **Load** window will appear.

2 Navigate to the location where the desired ChromaPure calx session file was saved.

3 Select the file, and then click **Open**.

ChromaPure will import all of the pre and post-calibration data from that saved session.

TIP: You can also import a calibration session by simply double-clicking a.calx file. ChromaPure will open and automatically load the information contained in that session.

Also, get in the habit of saving all of your calibration data in a single place. Use some naming convention-such as date of calibration, name of client, or both-that will allow you to easily call up specific data from past calibration sessions.

Calculating Lumens for a Front Projector

Overview

The Lumens Calculator module should be used for front projectors to calculate the peak output of the projector by an illuminance or a luminance reading. You can input several data formats into the calculator, including

- lux
- lumens
- foot-lamberts
- cd/m2

In addition to providing the necessary data input, you must also provide information about your screen. Once all of the information has been supplied, you may calculate the output of your projector in the same four data formats listed above.

To use the Lumens Calculator:

1. Display a 100% white test pattern.
2. Either turn on an illuminance meter (such as the AEMC CA813) and place up against the screen facing the projector lens; or, position a standard color analyzer facing the center of the screen with a minimal degree of offset.
3. Take a reading. The illuminance meter will read in lux, and the color analyzer will read in ft-L or cd/m2.
4. Make a note of the value returned from the reading.
5. From the Home Page, select Lumens Calculator.
6. Type the value you recorded in the Measurement Value field.
7. Select the correct Measurement Type (lumens, lux, ft-L, or cd/m2).
8. Type the screen size in inches.
9. Select the dimension in which the screen size is measured (diagonal or width).
10. Select the correct aspect ratio of the screen.
11. Select the gain* of the screen.
12. Click Calculate.

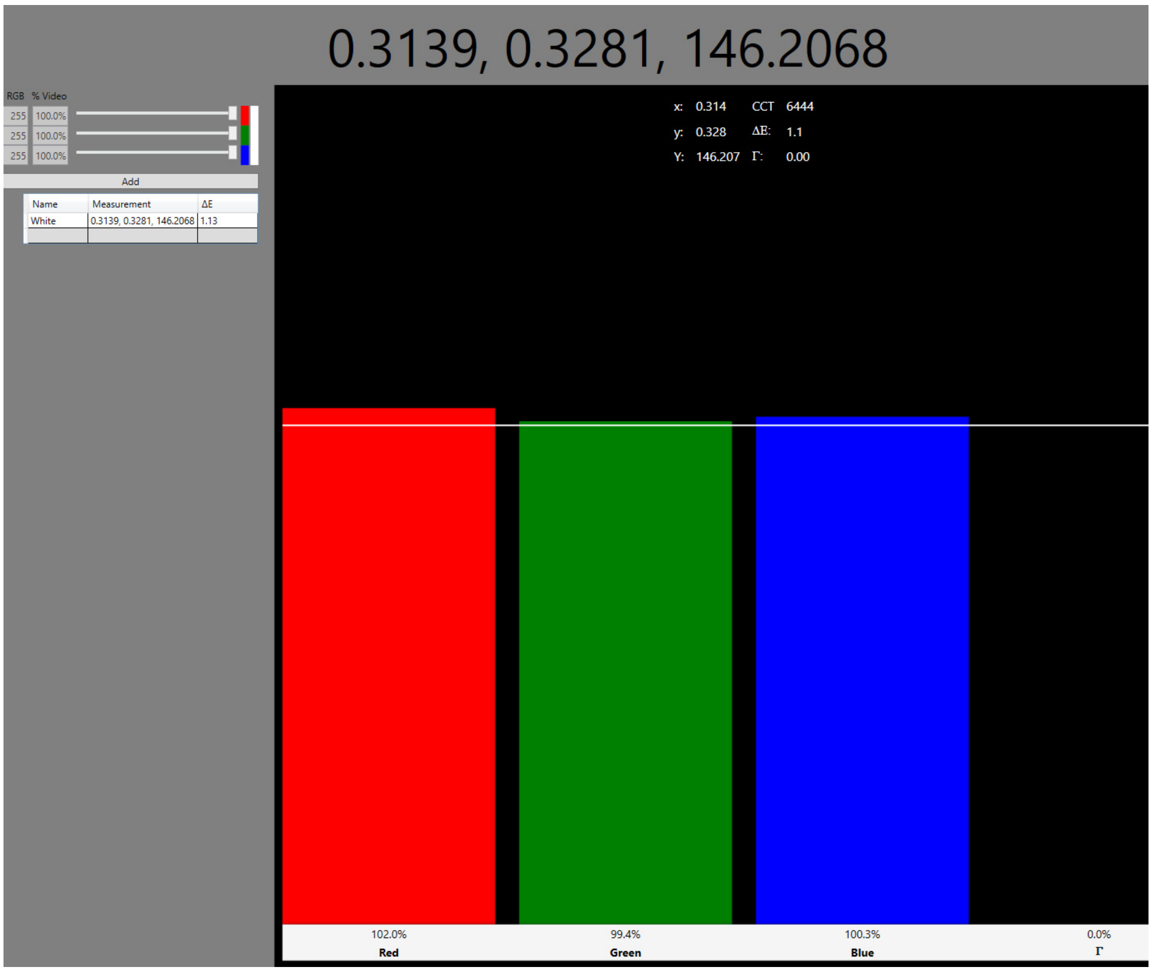
ChromaPure will return the selected value.

* Manufacturers routinely report gain figures that are inflated from the actual value.

Using the Raw Data Module

Overview

Use the Raw Data module for a wide variety of calibration tasks. You can take either single measurements or continuous measurements that appear in large xyY format. If you are using the meter correction or a signal generator, be sure to click the radio button to indicate the type of measurement (WRGBCYM) that you plan to take prior to clicking Measure. You can also use the included color picker to select a custom color.



The data you measure will appear in the grid on the right. You can export that data to a CVS file for analysis simply by clicking the Export button.

Working with a list of custom colors

Overview

The Raw Data module includes the ability to measure custom colors, indeed an entire list of custom colors of indefinite size. This can be very useful if you wish to collect a customized list of data that is not directly supported by the main application. For example, suppose you wanted to measure grayscale in more granular steps than 5% or color saturations in more granular steps than 25%. Indeed, there is no limit to the measurement scenarios you can create using this feature. Moreover, not only does this feature allow to easily and quickly measure a large number of user-defined colors, it also automatically report dE and gamma for each color and average dE and gamma for the entire list. If you wish additional data analysis you can export the data and open in Excel or some similar application.

To measure a list of custom colors:

1 Using Excel or some similar application create a list of colors, each defined by a linear RGB value. For example, if you wanted to measure 90% grayscale, you would type 0.9, 0.9, 0.9 in three contiguous columns in cells A1, B1, and C1. If you wanted 100% red, you would type 1.0, 0.0, 0.0. 75% blue would be 0.0, 0.0, 0.75, and so on. Any additional col-ors would be entered directly below this in cells A2, B2, and C2. You can enter as many colors as you wish, so long as you don't skip any cells or type a number that is larger than 1.0 or smaller than 0.

2 Once you have finished the desired list, save the file in the CSV format.

3 Click the **Module Options** button on the **Raw Data** module, and select **Load Custom Targets**.

A **Load xyY** window will appear.

4 Navigate to the location where you saved the CSV file described above, select the file, and then click **Open**.

The custom colors will appear in the **Raw Data** module with a reference white color automatically inserted at the beginning of the list.

5 Click the **A** button to measure all of the imported colors. (You need an active signal generator for this step).

When the measurements are complete, you will see a dE value next to each color, a gamma value, and average dE and gamma at the bottom of the series.

6 If you wish to export the list for additional data analysis, then from the **Module Options** button, select **Export Measurements**.

An **Export xyY** window will appear.

7 Select the desired location, file name, and file format, and then click **Save**.

Screen Uniformity

Overview

One of the characteristics of good video performance is consistent chromaticity and luminance across the entire screen. In fact, good white field uniformity is essential to a pleasing and accurate image. The Uniformity module provides the tools necessary to quantify your display's performance in this regard.

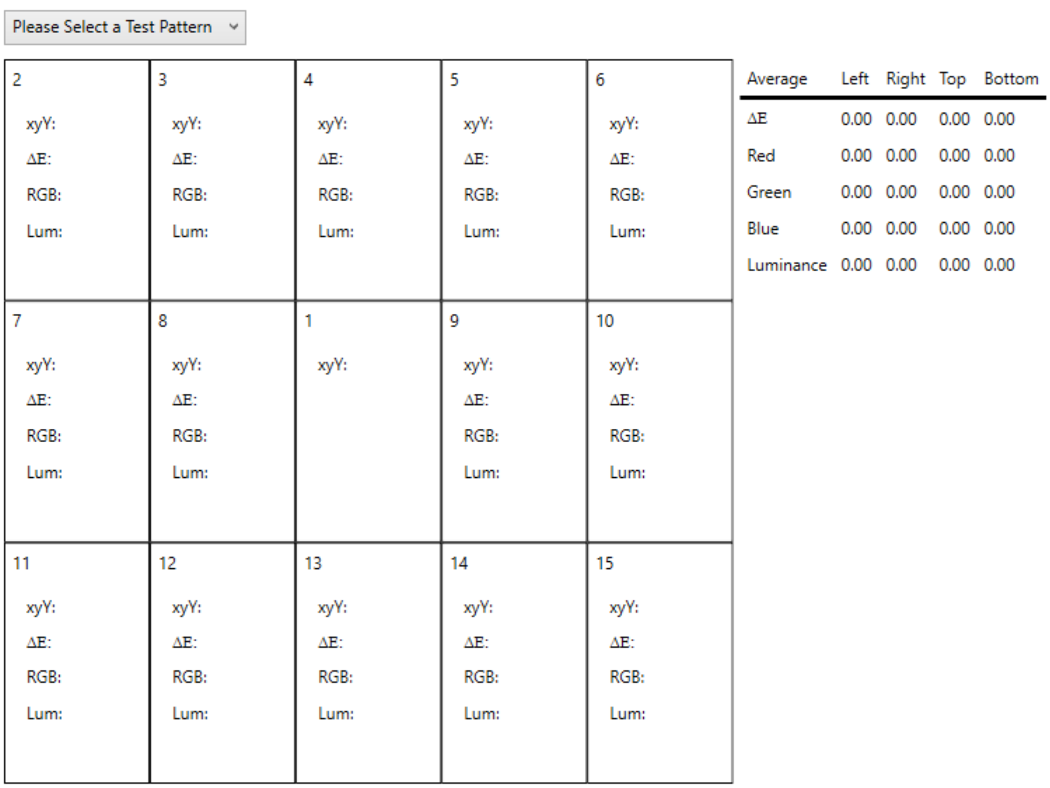
Unfortunately, in the great majority of cases this tool is purely diagnostic. Most displays offer little in the way of remediation of poor white field uniformity beyond selecting the best Picture preset.

NOTE: To use this module you will need a full field gray test pattern. Ideally, you would use two test patterns, one for the high end of the video scale and another for the low end. ChromaPure's Built-in test pattern generator provides test patterns for this purpose.

To measure screen uniformity:

1 1From ChromaPure's main interface click **Uniformity**.

The **Uniformity** module will appear.



2 Place the meter in the center of the screen, represented in the module as square number 1.

3 Display a full field gray test pattern of the desired video level. The drop-down will dis-play either an 80% or a 20% test pattern from ChromaPure's collection of Built-in test patterns.

4 Click inside square number 1 to take a reading. This measurement provides a baseline against which all of the others are compared.

5 One by one, move the meter around to each square taking readings as you go.

The data from those readings will appear in each square. Summary data will appear on the upper right of the screen.

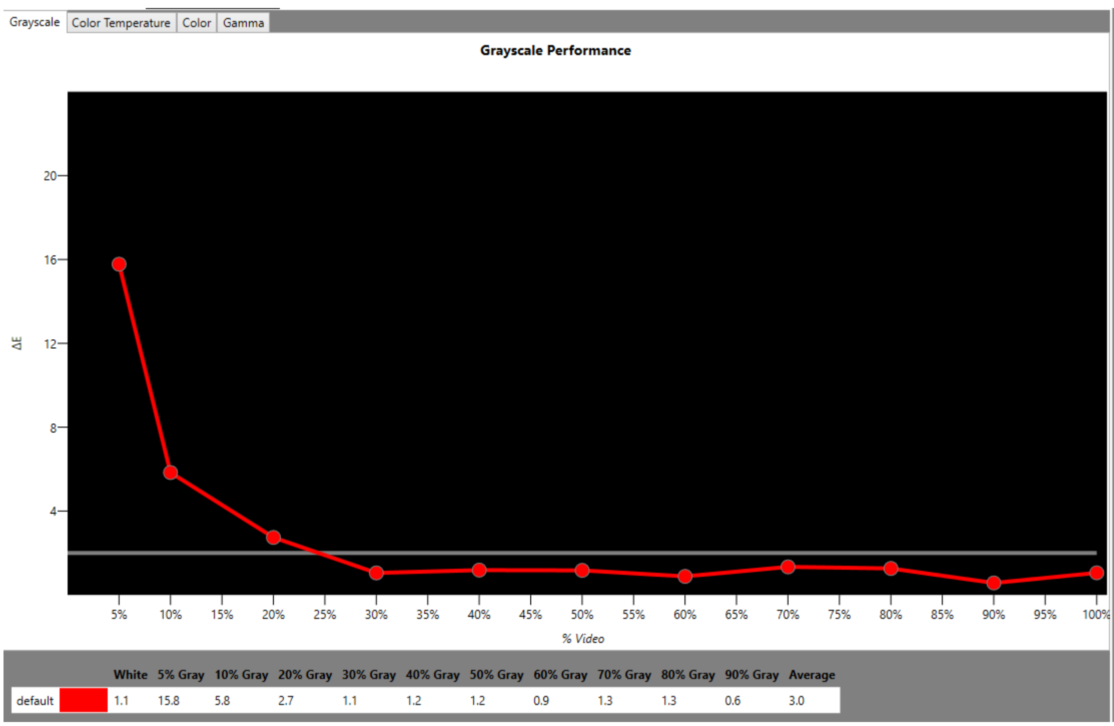
Measuring Display Performance

Overview

Sometimes you will need to characterize the general performance of your display to include the display's various picture modes. Use the Performance module for this task.

To measure display performance:

1 Open the **Performance** module.



2 Select the desired Picture preset on your display.

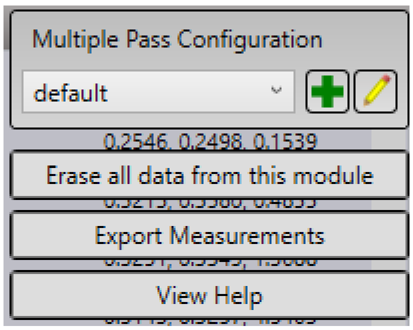
3 Click **Measure All (A)**. If you are using a disc, then display a 100% white test pattern and then click Measure (M), and then repeat this process until you have measured all of the colors in the list. Data will appear in four separate tabs:

- **Grayscale:** Records the dE of the grayscale.
- **Color Temperature:** Records the CCT of the grayscale.

- **Color:** Records the dE of an average of the saturations (20% or 25% increments) of the primary and secondary colors.
- **Gamma:** Records the gamma response of the grayscale.

4 Click the **Module Options** button.

5 Under **Multiple Pass Configuration**, click the pencil icon to put the label into edit mode.



6 Edit default to the name of the Picture preset you started with, and then click the check mark icon when finished.

This name will appear below the chart in the Legend.

7 Select another Picture preset on your display.

8 Click the Plus icon to add a new measurement pass.

9 Type the name of the second Picture preset, and then click the check mark icon when finished.

This name will appear below the chart in the Legend.

10 Take a full set of measurements as before.

11 Repeat steps 8-11 until you have finished all of the desired Picture presets on the dis-play.

Measuring the Spectrum

Overview

Color is defined by the wavelength of light. However, humans perceive color by virtue of color sensitive elements in the eye that respond to red, green, and blue stimulus. The combinations of red, green, and blue, in addition to our perception of the intensity of light is what constitutes all of our color vision.

The two methods for specifying color, measurement of wavelength and stimulation of RGB and luminous elements, provide the basis for the two types of color measurement instruments that we use for video calibration.

- The more common is the colorimeter. It, like the human eye, is a tristimulus device that responds to red, green, and blue light. It does this by collecting light and passing it through RGB filters onto photo-sensitive diodes. These filters mimic human color perception.

- The other type of instrument measures color directly by measuring the intensity of light at set wavelength intervals. These instruments are spectroradiometers, and they are generally considered more accurate devices because they measure color directly with-out relying on filters. However, in addition to expense, spectroradiometers have some disadvantages. In particular, because they slice light up into many, many discreet pack-ets for each specified wavelength interval (50-200), the intensity of light for any one of these is relatively small. That means that the instrument is relatively slow to return a reading and it is relatively insensitive to very low light levels. Because colorimeters only divide light into three segments of red, green, and blue this issue does not arise.

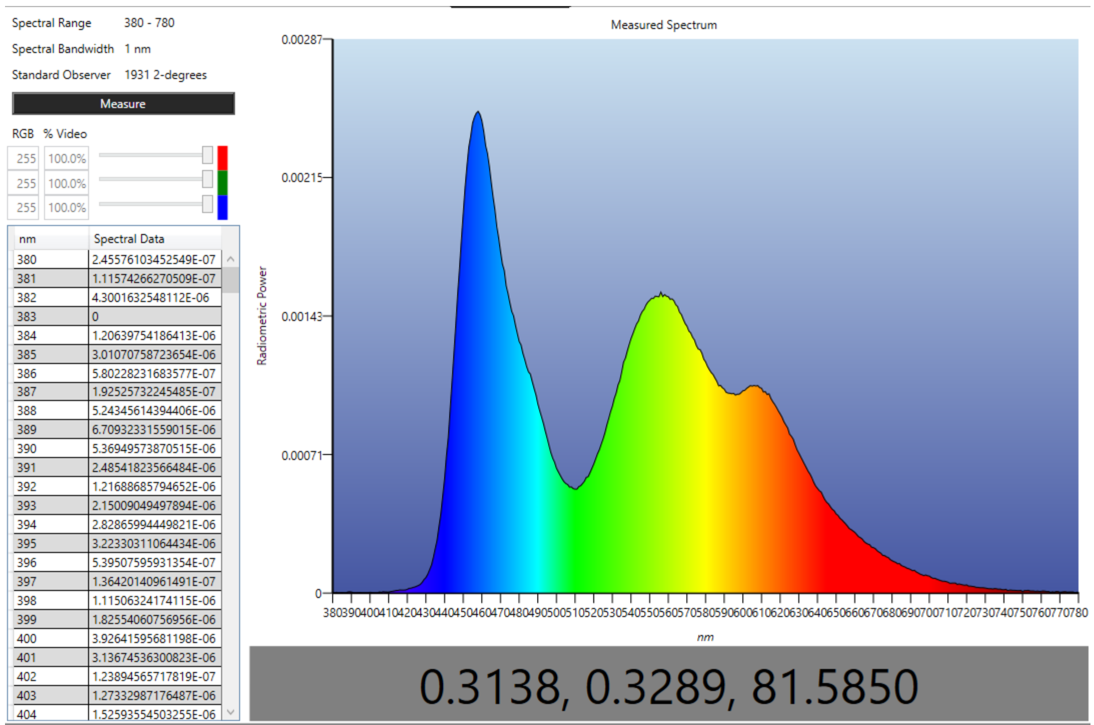
The color system that is generally used today was developed in 1931, and perhaps its core achievement was experiments that characterized normal human color perception and correlated it with wavelengths of light in the visible spectrum. This resulted in the 1931 Standard Ob-server, which contains three color matching functions. Using simple math you can then use these color matching functions (CMFs) along with measured values in the visible spectrum to derive a colorimetric value of XYZ. From XYZ we have derived all of the color spaces that we commonly use to characterize color appearance, such as xyY, RGB, Lab, and Luv.

A spectroradiometer simply measures light at set wavelength intervals and then uses the 1931 CMFs to derive a colorimetric value. The Spectrum module in ChromaPure displays the raw spectral data and renders it on a chart that identifies the colors that correspond to the visible spectrum of light, much like a rainbow. Thus, the Spectrum module only works with spectroradiometers. The following devices are currently supported.

- JETI 1211
- JETI 1501/1511
- X-Rite i1Pro/i1Pro2
- Colorimetry Research CR-250/300

To take a reading of the spectrum:

Use the sliders to display the desired test pattern, and then click Measure. Spectral data will appear in both numeric and graphical formats. If you wish to work with the spectral data independently, you can copy/paste the data from ChromaPure into Excel or some other application.



Taking Screenshots

Overview

It is often useful to take screenshots of the ChromaPure user interface and measured data. Perhaps you want to share data with others or wish to document a feature or report a bug. You can also take a screenshot in lieu of running a report for the data on this screen.

To take a screenshot of a ChromaPure chart:

Right click on the chart and select either:

- Copy chart to clipboard
- Save chart as image

To take a screenshot of the entire ChromaPure window:

- Right click the ChromaPure banner at the top left of the screen and select either
- Copy chart to clipboard

Chapter 6: Video Calibration Concepts

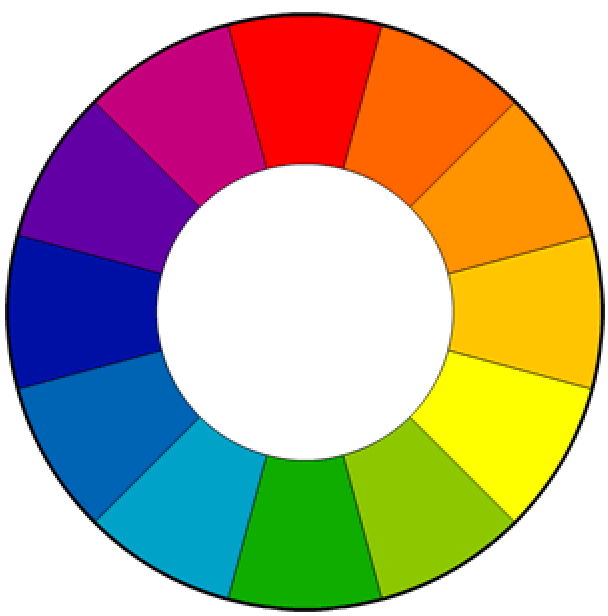
What's Inside?

Color Concepts

One of the helpful ways to conceptualize color is to think of it in geometrical terms. There are at least a couple of ways to visualize the color spectrum.

The Color Wheel

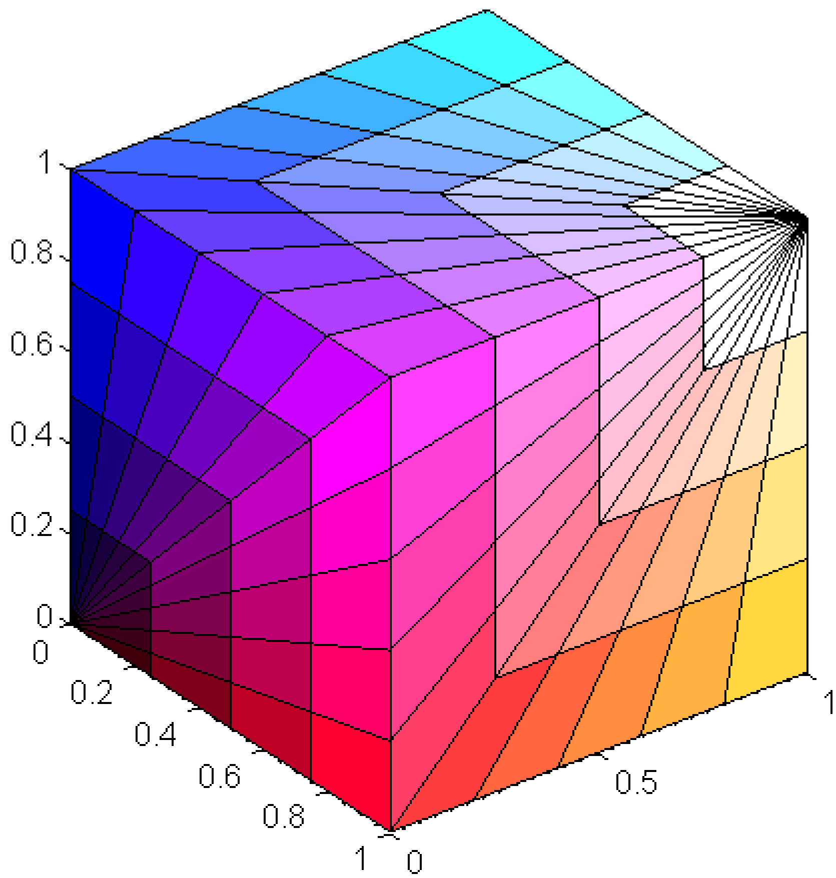
The primary and secondary colors, shown in 360 degrees on the color wheel.



Placement on the color wheel defines the hue of a color. Hue is the primary characteristic by which we distinguish one color from another.

The Color Cube

Color is a three-dimensional property, and the color wheel only helps us to visualize one of those dimensions (hue). The color cube is a popular image because it represents all three dimensions of the range of color.



Dark Reading Requirements

All color analyzers have some level of noise. The ratio between the inherent noise of the sensor and the level of the signal being measured is the signal-to-noise ratio. This number should be as high as possible.

The way the color analyzers attempt to minimize the effect of inherent noise is to take a dark reading. Since there is no external signal being measured, any data will be from the noise floor of the instrument itself. Once measured, this can be subtracted from all subsequent readings, which increases accuracy.

All color analyzers use this technique. However, some simply build a sample of the noise floor into the unit's firmware, so it doesn't have to be measured.

- The X-Rite Display 3 does not require a dark reading
- The X-Rite Chroma 5 does not require a dark reading.
- The Spyder3/4/5 does not require a dark reading.
- The basICColor Discus does not require a dark reading.
- The Display 2 and DTP-94 require a single dark reading at the beginning of the calibration session.
- The X-Rite i1Pro requires an initial dark reading at the beginning and subsequent periodic dark readings throughout the calibration session.
- The X-Rite Hubble requires an initial dark reading at the beginning and subsequent periodic dark readings throughout the calibration session.
- The Klein K-10 does not require a dark reading.
- The Colorimetry Research CR-100 does not require a dark reading.
- The Minolta CS-200 does not require a dark reading.
- Reference spectroradiometers-such as the JETI, Minolta, Colorimetry Research, and Photo Research units-automatically take dark readings as part of the measurement process.

Reference Gamuts

Color	x	y	Y
		Rec. 709	
Red	0.6400	0.3300	0.2127
Green	0.3000	0.6000	0.7152
Blue	0.1500	0.0600	0.0722
Yellow	0.4193	0.5052	0.9278
Cyan	0.2247	0.3288	0.7873
Magenta	0.3209	0.1542	0.2848
White	0.3127	0.3290	1.0000
		SMPTE-C	
Red	0.6300	0.3400	0.2124
Green	0.3100	0.5950	0.7010
Blue	0.1550	0.0700	0.0865
Yellow	0.4209	0.5066	0.9135
Cyan	0.2306	0.3262	0.7876
Magenta	0.3145	0.1606	0.2990
White	0.3127	0.3290	1.0000
		EBU	
Red	0.6400	0.3300	0.2220
Green	0.2900	0.6000	0.7067
Blue	0.1500	0.0600	0.0713
Yellow	0.4172	0.5018	0.9287
Cyan	0.2197	0.3287	0.7780
Magenta	0.3271	0.1576	0.2934

White	0.3127	0.3290	1.0000
	DCI-P3		
Red	0.6800	0.3200	0.2095
Green	0.2650	0.6900	0.7216
Blue	0.1500	0.0600	0.0689
Yellow	0.4248	0.5476	0.9311
Cyan	0.2048	0.3602	0.7905
Magenta	0.3424	0.1544	0.2784
White	0.3127	0.3290	1.0000
	Rec. 2020		
Red	0.7080	0.2920	0.2627
Green	0.1700	0.7970	0.6780
Blue	0.1310	0.0460	0.0593
Yellow	0.4465	0.5374	0.9407
Cyan	0.1465	0.3446	0.7373
Magenta	0.3682	0.1471	0.3220
White	0.3127	0.3290	1.0000
	Adobe RGB		
Red	0.6400	0.3300	0.2973
Green	0.2100	0.7100	0.6274
Blue	0.1500	0.0600	0.0753
Yellow	0.4271	0.5181	0.9247
Cyan	0.1748	0.3286	0.7027
Magenta	0.3548	0.1728	0.3726
W	0.3127	0.3290	1.0000

Understanding Delta-E

Overview

Delta-E (dE) is a measurement of color error relative to a known standard. Thus, the goal in calibration is to get the dE of the measured color as low as possible.

There are several different dE formulas.

- CIELAB
- CIELUV
- CIE94
- CIEDE2000

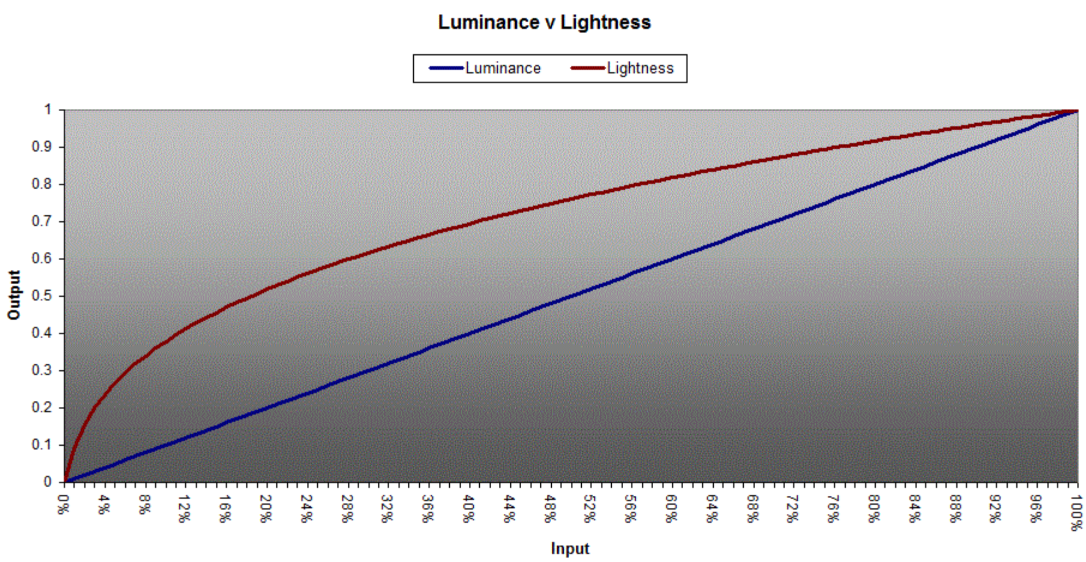
Each formula produces somewhat different results and has different tolerances. We recommend using CIE94, though CIELUV is also a good choice for grayscale.

When using CIE94 or CIEDE2000 strive for a value of 1.5 or less (1.0 and below is visually perfect) for color and 3.0 or less (2.0 or less is visually perfect) for grayscale. If using CIELAB or CIE-LUV, strive for 4.0 or less for all readings.

Lightness and Luminance

Overview

Both are a measure of the intensity of light. Lightness is a non-linear, perceptually-weighted unit of intensity that is approximately the inverse of display gamma. Human vision is very sensitive to even small changes in the intensity of light under dim conditions, but less sensitive to similar changes under bright conditions. As the graph below shows, at only 18% of the total level of intensity we already perceive approximately half of the difference between black and peak output.



Luminance is a linear unit of intensity that can be expressed in absolute or relative terms.

- Absolute luminance is expressed in raw cd/m2 or ft-L.
- Relative luminance is expressed as a number between 0.0-1.0, where 1.0 is equal to the absolute luminance of the white reference.

The **Color Management** module uses lightness. The **Color/Tint** module uses relative luminance. The **Pre/Post-Calibration Grayscale** modules and the P**re/Post-Calibration Color Gamut** modules use both relative and absolute luminance.

One of the obvious consequences of the difference between lightness and luminance is that the difference in lightness between a bright color (green) and a dim color (blue) is much smaller than it would be if expressed in luminance (relative or absolute). Green luminance is approximately 71% of reference white, whereas blue luminance is approximately 8%-a ratio of nine-to-one. However, the same difference in expressed lightness is a ratio of less than three-to-one. One way to think of this is that the intensity of green measures 9 times brighter than blue, but green only appears to the eye as 2.7 times brighter than blue. This is what we mean by when we say that perception of the intensity of light is non-linear.