ENTERTAINMENT TECHNOLOGY CENTER

"VIRTUAL PRODUCTION"

WHITE BALANCING TUTORIAL

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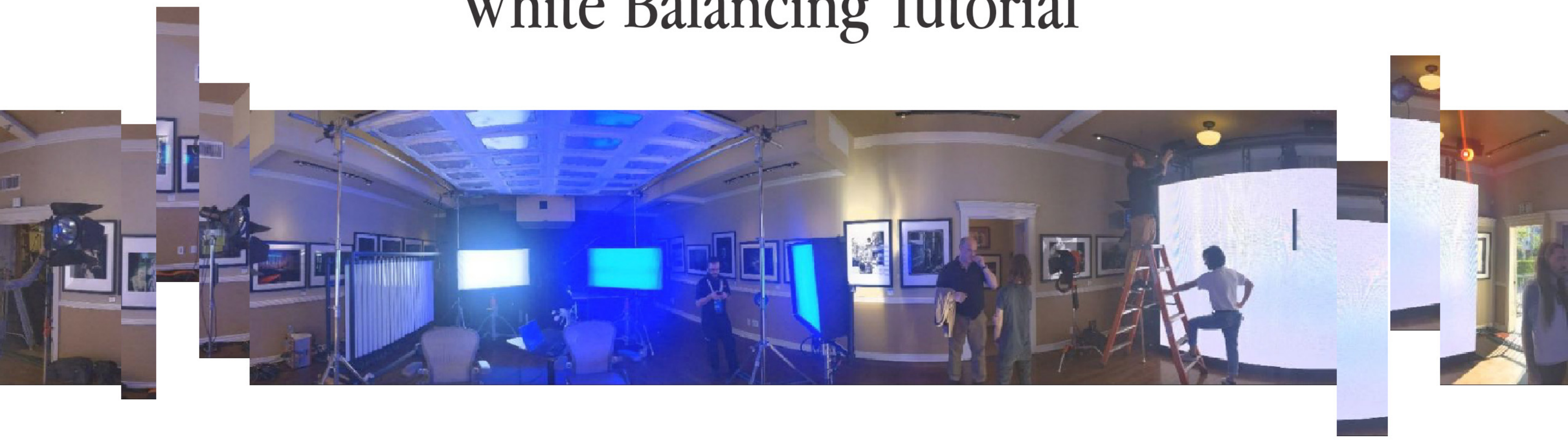
White Balancing Tutorial



INTRODUCTION.

Consider the following scenario: A tech-savvy cinematographer begins preparations for a curved wall LED volume shoot. On her tech scout, she directs the volume technician to display a white frame on the warmed up LED wall to measure its correlated color temperature (CCT). She pulls out her spectrometer, stands at the center of the wall's radius, and confirms with satisfaction that it outputs a CIE D65 white point.

On the first day of production, she then returns to the stage with her camera and lighting crew. Her 1st AC dials in 6504K as its shooting CCT setting, and the lighting technicians light using fuller LED spectrum fixtures set to D65 as their white point. She then meters the fixtures to confirm that they indeed meter at the CIE 1931 x, y coordinates of CIE D65.

Due to the hubbub of production, she felt no need to correlate the final foreground and background color balance with a fixture-lit gray card and gray step chart on the wall using a vector vectorscope. A few months later, she sits in the final color grade to find all the wall content skewing significantly magenta vs her lit foreground talent and sets.

What happened? Did the fault lie in her meter, the camera, the LED wall, or the lighting fixtures?

PROBLEM STATEMENT.

Due to the large amount of LED volume or backing wall applications cropping up worldwide, many critical, but misunderstood color calibration issues have manifested due to complex color science-based problems. A relatively low supply of qualified technicians prevents filmmakers from knowing the need nor means to calibrate their workflow to deliver a visual color quality consistent with legacy color workflows. The deceptively simple concept called "white balancing" can lead to different degrees of confusion or, at worst, a complete reshoot. This problem stems from different technical reasons:

1. Typical digital camera vision **does not match** CIE 1931 observer vision (Figure 1), aka human vision
2. Extreme spectral differences exist between fuller spectrum lighting fixtures & LED walls (Figure 2)
3. Different white balancing methods exist
4. Many different possible workflow points can control white balance/calibration

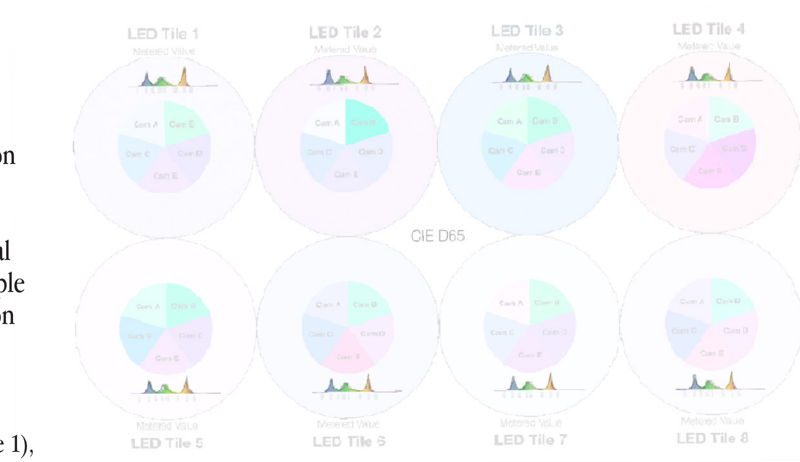


FIGURE 1: An assay of the metered color (CIE 1931 x,y converted to sRGB RGB values) 8 different LED tiles from multiple manufacturers compared with the "seen" color by 5 different cinema cameras. The "seen" color shown was generated by recording in RAW, setting the white balance to 6504K with the proper tint adjustment for D65 specification white, and displaying the normalized RGB trio directly converted to sRGB values from the manufacturer wide gamut color space. As expected, no camera "sees" the video tile white balanced RGB LED spectrum exactly as CIE 1931 x,y specification.

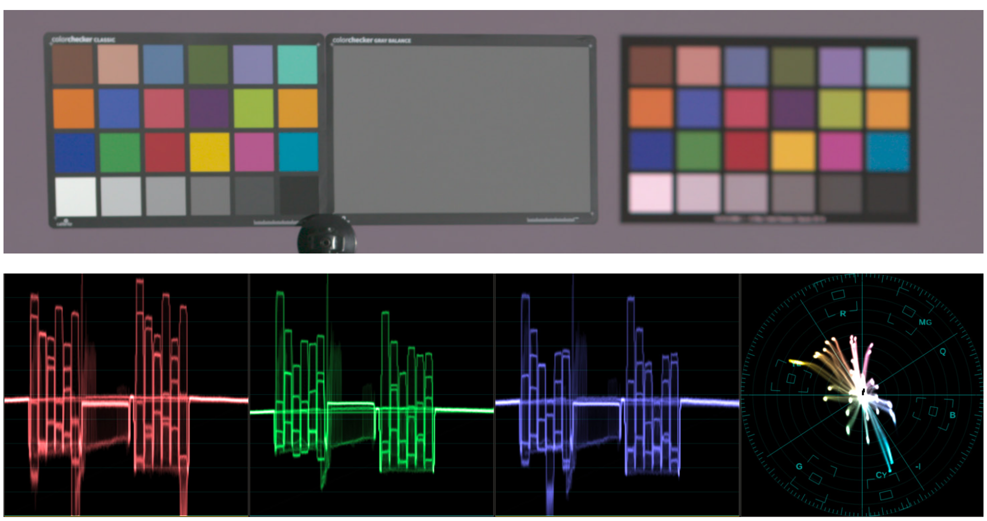
FIGURE 2: An LED wall was white balanced to match the same colorimetric value for CCT: 6585K, duv: 0.0038 of the fuller spectrum LED fixture (as seen in the meter reading) lighting the live chart and test subject. The wall graphics include an 18% gray horizontal stripe, a digital Macbeth chart from ColourScience.org, a 25-stop gray wedge chart, and a still frame from the American Society of Cinematographers (ASC)

PROPOSED SOLUTION.

Cinematographers need a **simple graphical tutorial** that breaks down the problem between camera & its LED wall perception, then present a solution in a succinct manner. The tutorial needs to discuss the global technical perspective a cinematographer needs, as well as provide a map for the different means to implement the solution.

METHODS

IDEAL PHILOSOPHICAL APPROACH



In any rear projection type of photographic workflow, the photographed display technology must closely emulate real world environments as technically possible (Figure 3).

Full tonal range and color space values must accurately map within a camera's calibrated color space according to the original physical conditions used to create the camera manufacturer's calibration.

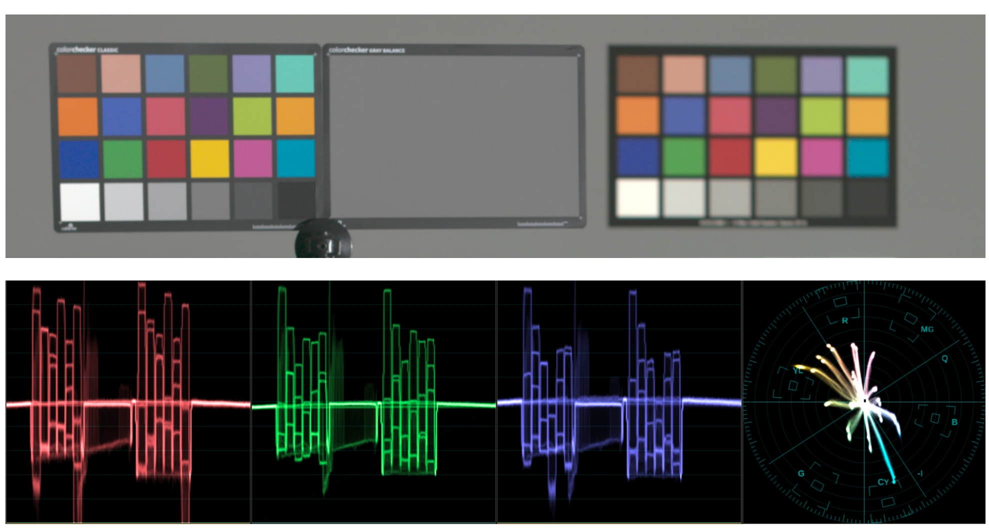


FIGURE 3: The LED wall content from Figure 2 (the top panel) was white balanced via chromatic adaption directly of the content using, as feedback, the unprocessed camera video signal via vectorscope and RGB parade waveform scopes (2nd & 3rd panels). To achieve a closer RGB balance to the physically lit gray card (the third panel), the camera white balance was fixed to the card's RGB response, and the software chromatic adaptation operation was applied to the content until a clos match was achieved in the scopes. Live camera view & scope readout courtesy of Assimilate LiveFX software.

IDEAL COLOR TEMPERATURE

Since most video standards use CIE D65 as its white point, cinematographers should first calibrate their workflow at D65 as a starting point setting in their camera. D65 ensures the least amount of potential points of color space computation error at the workflow's foundation. To do this, cinematographers can set the camera CCT white balance setting to the CIE D65 CCT value: **6504K**. Since this is such a fine grained value unavailable in many cameras, 6500K will suffice as the most realistically available option for the majority of practical applications. After that, the displayed content's white point can be balanced via software to generally match any chosen camera CCT and tint setting.

HOW TO EVALUATE ON-SET WHITE BALANCE & COLOR MATCH

The corollary to the finding that camera sensor response does not match CIE 1931 observer vision is that color matching an LED display to a foreground element with your eyes is unlikely to result in a color match for the camera output.

Always judge the accuracy of color matching via the camera output, either with a scope or reference monitor, and resist the urge to evaluate on-set color match by looking at the LED display and foreground elements directly with your eyes.

WHAT & WHERE TO WHITE BALANCE

Should the cinematographer white balance the camera to the wall, or should the LED wall display technicians white balance the wall to the camera?

A) If the **cinematographer** white balances the camera to the LED wall, then the lighting team will have to white balance all fixtures to that new custom white point. This solution *can* work if minimal light fixtures are used, but extra source of error lies in requiring the lighting crew to balance every fixture used on set with this inevitably non-standard white point value. Due to the potential amount of fixtures and imprecision in achievable accuracy in every fixture, this method should be avoided.

B) If either the **display technician** or **volume content team** white balances the LED wall to the camera's white point set in camera, this solution significantly reduces the overall color workflow complexity and sources of error. Virtual art department (VAD) or the video playback team then can shift the displayed content's white balance to match the camera's final set white point.

HOW TO WHITE BALANCE A WALL

LED wall display technicians have different tools of increasing complexity, but greater accuracy, to fully white balance displayed content. The following wall team instructions assume the entire wall already has batch-matched & pre-calibrated tiles.

Pre-White Balance Setup:

1) Minimize off-axis viewing of the wall by proper camera placement:
   a. Perpendicular / on-axis to the horizontal and vertical center of the LED display
   b. For **flat** walls, place at *furthest* possible distance and crop in with a telephoto lens
   c. For **curved** walls, place camera at the wall curvature diameter's center. Ideally, the camera height should also match the center of the wall height.

2) Defocus the lens so the waveform monitor readout appears to be a thin bar (uniform field color, no moire patterns).

3) Camera output signal should be set to native log output and desired camera color gamut setting with no color processing applied.

WHITE BALANCE METHOD: SIMPLE VERSION

FIGURE 4: White balancing via the LED processor (or other rear projection device's color setting menu) provides the simplest way to balance wall content to a camera. The top image pair indicates a typical system default white point, which trends slightly magenta in camera. The middle pair shows the adjustment necessary to white balance a 36% gray card displayed on the wall via a user's spectrometer—placed at the center of a wall's curvature—to official CIE D65 specification, and the resultant camera mismatch. The bottom pair shows how using LED processor CCT & the tint controls balanced the image within the camera. This method works generally sufficiently well for most applications. However, note that this method may introduce some undesired color shifts in the image. Example LED processor software interface courtesy of Brompton Technology, Ltd.

1) **Warning**: *does not guarantee consistent color balance throughout the entire tonal range*!

2) Output a properly tone-mapped, full screen neutral density wedge image—or a solid light gray image—onto the wall. Ideally, one should display a test pattern on the LED display at 18% medium gray to 72% light gray of the signal, or between 18-72 nits of the display.

3) Feed the camera log-encoded output into an accurate vectorscope or RGB parade waveform monitor

4) Use the LED wall processor(s) control in the following order to white balance the test pattern image within camera (Figure 4):
   a. CCT
   b. Tint and/or RGB Gain tools

WHITE BALANCE METHOD: INTERMEDIATE VERSION

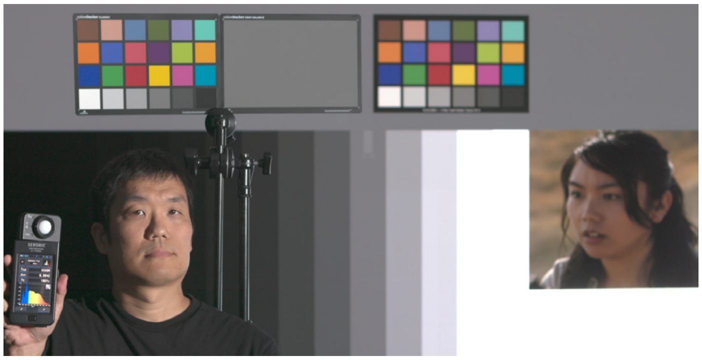
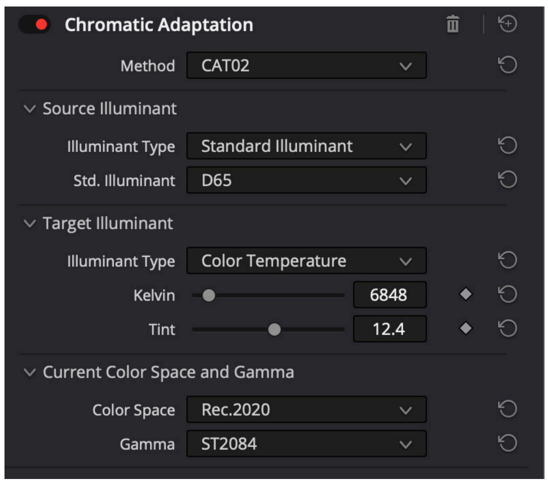
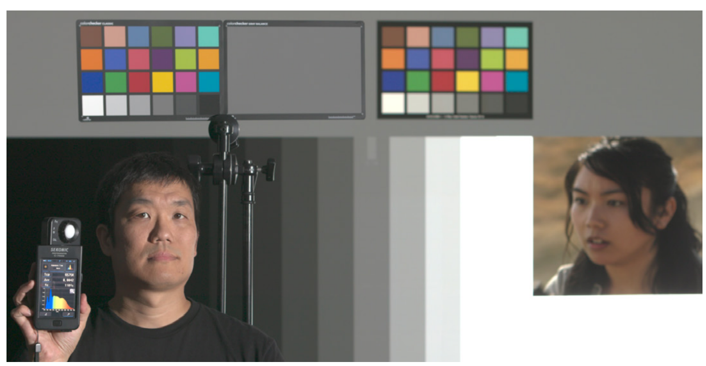


FIGURE 5: White balancing via the content's native color space provides the simplest way to balance wall content to a camera. This method may still introduce some, but less obvious particular color shifts in the image in comparison to simple RGB balancing within the display processing software. Example software interface courtesy of Blackmagic Design Pty, Ltd.





1) In the content generation or playback software, use a chromatic adaptation plugin or operation function set to the LED Display output color space to apply an intended color shift to the final output of the content before sending the content to the display.

2) This method offers a significant improvement over display processor simple RGB gain type white balancing, but chromatic adaptation models do not always correspond to correctly remap captured camera content.

3) One can place this chromatic adaptation plugin value at the end of the color processing chain, or bake it into a 3DLUT to load into the LED processor if possible.

WHITE BALANCE METHOD: COMPLEX VERSION

1) Use a bespoke calibration program that uses **direct production camera input** to fully linearize and white balance the wall's complete tonal range and color gamut with the camera CCT set to 6504K. This process happens **independently** from the system content.

2) Calibration programs and systems create "neutralizing" color correction transforms that take into account the entire color gamut volume for a given combination of LED wall + production camera lens & filtration + camera sensor. Examples include:

   a. OpenVPCal - Netflix open source calibration software (written in Python; relies upon The Foundry Nuke VFX software and some means to play back OpenEXR format files correctly on screen)
   b. Assimilate LiveFX
   c. Light Illusions Colour Space
   d. Portrait Displays Calman (TBD)
   e. Sony - VP calibration tool that calibrates the LED wall to Sony Venice **family** of cameras

3) Load the generated color correction transform into the **final** part of the LED processor's color adjustment chain. *No corrections should take place after applying this transform!*

4) Adjust the content's white point to the production camera white point setting dictated by the cinematographer (e.g., 3200K, 4300K, or 5600K) and camera/LED display wall interaction. Confirm the calibration using the waveform monitor with this new calibration.

WHITE BALANCE METHOD: LAST RESORT

If **these options don't** exist in a virtual production scenario, the cinematographer must then white balance the camera to the wall at the ideal content white point, and the lighting crew must then compensate for the new white balance in every fixture.

What ideal methods should a lighting team use to implement successful white balance controls? AFTER the camera is white balanced to the wall ideal content white point, the cinematographer and lighting team must set up a properly exposed 18% gray card and light the card with the different types of fixtures. With an RGB parade, RGB histogram, or vectorscope metering the camera's log output, the lighting team cam adjust each fixture type's white point until the gray field creates the same value in R, G, and B channels.