VideoEq Technical Overview

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Overview

The VideoEq provides a quick and easy method to accurately correct and calibrate color on any HDMI based video display. The underlying algorithms for making these adjustments are based on industry-standard and proven techniques. The VideoEq provides a unique two-stage processing pipeline that is extremely powerful, yet straightforward to adjust.

Display Calibration

In the days when all displays were based on CRT technology, achieving color accuracy across displays was relatively simple. The colors reproduced by a CRT are determined by the colors of the phosphors used in the manufacturing process. In production, there were a fairly small number of different phosphor colors. If two displays had the same phosphor, then it was relatively simple to get the processing circuitry aligned to provide very closely matched displays.

Now, with the multitude of digital displays available, matching across displays is much more challenging. To further complicate the issue, these displays are physically smaller and lighter; and new industries such as digital signage are mounting them in arrays to provide large format displays. In these arrangements, color matching is even more critical than ever; even one un-calibrated panel can destroy the aesthetics of the entire "wall".

Color accuracy in digital displays is a combination of several factors, dependant on the underlying technology. Plasma displays, like CRTs depend on the phosphor chemistry. LCDs depend on two factors – the color (and technology) of the backlight and the color of the filters used in the TFT panel itself. Projection technologies are similar to LCDs in that the colors depend on the lighting element and the filters used.

Market research has shown that consumers are attracted to bright and vivid pictures. Therefore, many manufacturers choose to engineer and calibrate their displays to look the brightest and most vivid on the showroom floor. Since these panels are targeted at high volume consumers, they tend to have low prices. These low prices are attractive to commercial integrators looking for low cost video display solutions. Unfortunately, because these panels are not engineered for accurate color reproduction, the integrator faces many difficulties when trying to use these panels in a system where color quality is important.

VideoEQ™
Technology by X-Vue, LLC

Colorspaces / Color gamuts

Video standards bodies such as the ITU and SMPTE have ratified standards defining colorspaces for video reproduction. There are two mainstream colorspaces used in digital video: Rec601 for standard definition, and Rec709 for high definition. Calibrating video displays for accurate and consistent color ultimately rests on processing the input signal so that the primary, secondary, and white colors match one of these standards.

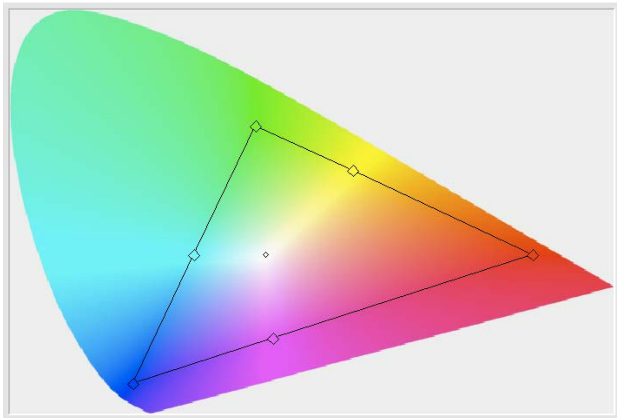

Figure 1 - CIE showing the Rec709 Gamut

As long as the display manufacturer has designed the display for a gamut that is wider than these standard colorspaces, it is possible to calibrate the display through processing techniques to achieve the standard colorspace.

Figure 1 shows a CIE diagram with a Rec709 color gamut triangle outlined for reference. A display is capable of reproducing any color inside its "gamut triangle".

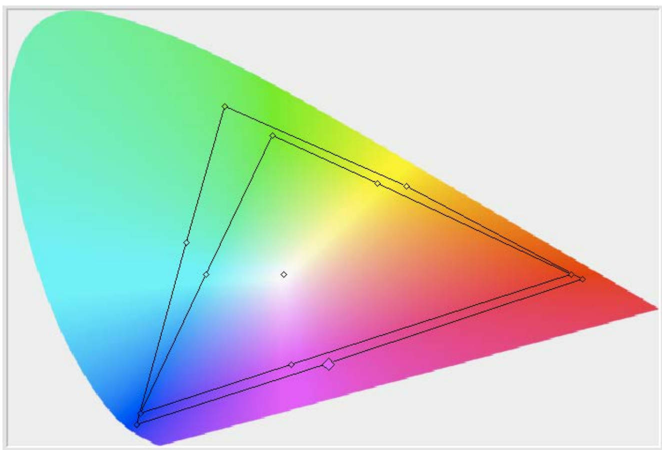

Figure 2 - CIE Diagram showing a Display's "Native" gamut and the Rec709.

Figure 2 shows a representative "native" gamut (the larger distorted triangle). This gamut can be calibrated to the reference standard Rec709, by manipulating the primary and secondary color points.

Luminance

These color standards also specify how intensity should change with increasing color component value. This is often referred to as a "gamma" curve. Typically this curve will be an exponential response, as shown below.

Figure 3 - Typical "Gamma" curve.

However, manufacturers often distort this curve in order to make the display appear brighter and more vivid. Figure 4 shows an "S-curve" response that will increase the apparent contrast of a display.

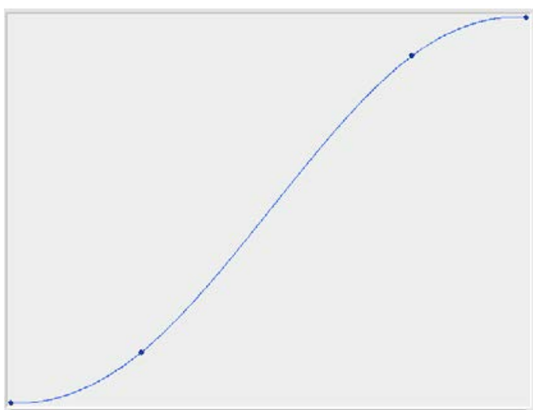

Figure 4 - S "Gamma" curve.

As with the color gamut calibration, it is possible to calibrate this response to achieve consistent and accurate image reproduction.

VideoEq's Solution

The VideoEq solves these two calibration challenges by providing both a lookup table (LUT) for each color component (Red, Green, and Blue), and an independent 6-color Color Management System (CMS).

The Lookup table is used to correct for a non-linear (or non log-linear) luminance response, as well as adjust the white point. The CMS is used to correct any error in the color primaries and secondaries.

The lookup table is a simple input-to-output mapping of colors. When the VideoEq receives a certain level of input color, it uses that value as an index in the lookup table and then outputs the table value at that index. Conceptually, the lookup table operation can be thought of as a "shift" or perhaps an "add". Even though the LUT is one of the most flexible operators in modern image processing, there are still some things that cannot be corrected using a 1D LUT. For example, an image cannot be desaturated, nor can an image's colors be adjusted without affecting the white balance. For the graphic artist, the LUT is analogous to Adobe Photoshop's "Curves" tool.

The CMS matrix provides a companion to the LUT. Conceptually, the CMS can be thought of as a "multiply" operation. The VideoEq divides the color gamut into 6 sectors, and then independently corrects the colors based on the adjustment settings. The VideoEq's algorithms allow these sectors to seamlessly blend. This CMS matrix allows hue, saturation, and brightness to be adjusted separately for each sector. The VideoEq's CMS system is functionally equivalent to Adobe Photoshop's "Channel Mixer". However, the CMS allows for a separate "Channel Mixer" setting for each primary and secondary color.

Figure 5 below shows the power of this six-color CMS design. The CIE diagram with the secondary colors fully desaturated, while the primary colors are left unaffected. Even though this extreme level of adjustment is not necessary for an accurate display calibration, it shows the power of the VideoEq's controls.

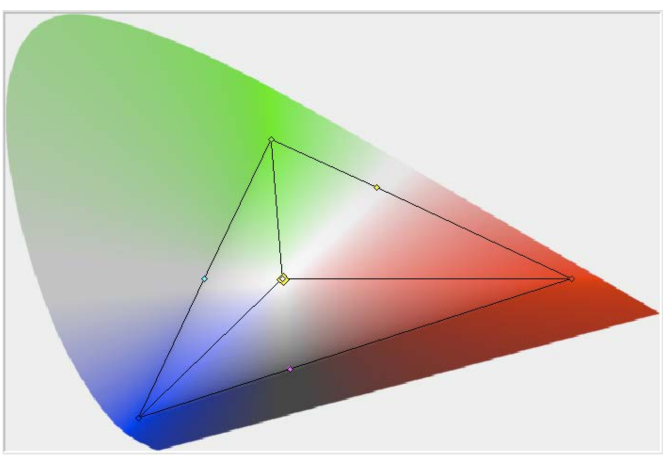

Figure 5 - CIE diagram with desaturated secondary colors.

The VideoEq combines these two operations in a pipeline architecture, first applying the Lookup Table, then applying the CMS matrices. Again, using the Photoshop analogy, this can be thought of as using two "adjustment layers".

Video Formats – Including 3D!

When we designed the VideoEq, we recognized that many of the functions a traditional outboard video processor performs were becoming obsolete. The processing, switching, and scaling performed by modern commodity equipment is really quite good. Color processing, on the other hand is something that very few devices get right.

Since the VideoEq does not do any scaling or noise reduction, there is no need for a frame-buffer. This design allows the VideoEq to support virtually any video format[1], including the new 3D formats. It does this by letting the video source and video display agree on the video details, then simply processes the color on the way through. The VideoEq preserves vital signal information such as color-space, bit depth, and the HDMI InfoFrame metadata, making it a robust and seamless addition to the system.

Video Calibration with the VideoEq

The Equipment

Calibrating a VideoEq is not a difficult task, but it does require a few tools and some patience. You will need the VideoEq, a computer, a color analyzer, calibration software, and a video generator (or other method of displaying test patterns).

The computer you use largely depends on the software and color analyzer you are using. The VideoEq control utility is available for download at www.videoeq.com. VideoEq will also work with some 3rd party calibration software tools directly.

[1] Subject to the pixel clock limits of the internal chips.

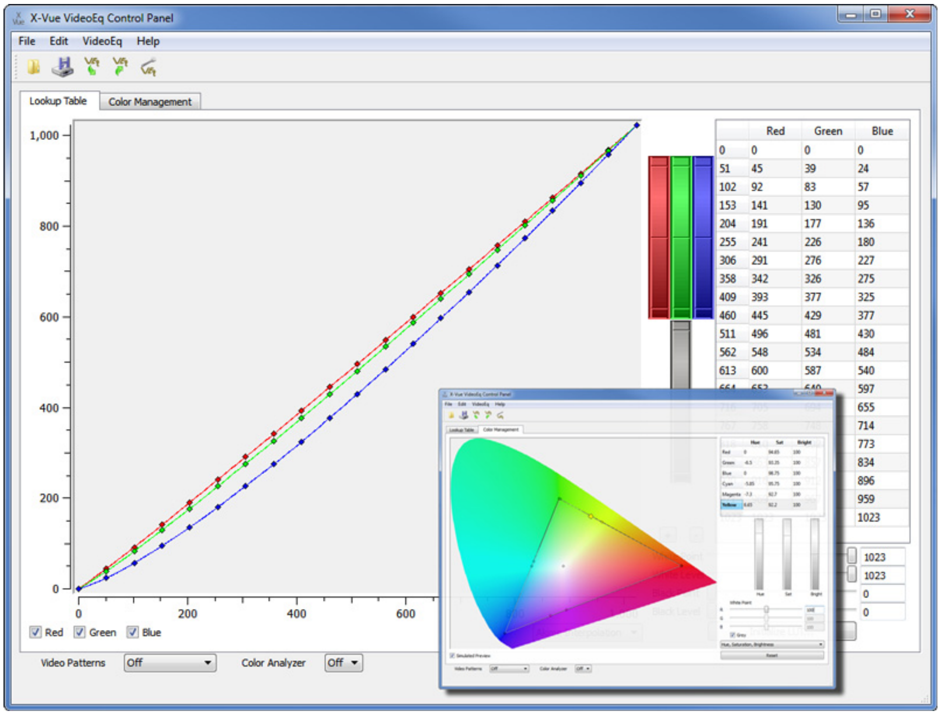

Figure 6 - VideoEq Control Software

In order to calibrate the VideoEq, you need a way to display reference test patterns through the VideoEq such as a digital video generator. A reference DVD or Blu-Ray disk will also work well.

The Process

The VideoEq is designed to sit in between an HDMI source and the display. We will assume that you are able to connect the pattern source to the VideoEq, and the VideoEq to the display. You will also need to connect the VideoEq to your computer with the supplied USB cable. You will also need to connect your computer to the video source and the color analyzer, as is appropriate for your calibration software.

We recommend that you first perform a "baseline" calibration of the display, at a minimum setting the black level (brightness) and white level (contrast). After the display is calibrated, we recommend that you reset the VideoEq's Lookup Table and CMS controls to a neutral position. This is important because of the pipeline architecture. To be specific, we want to use the LUT to compensate for and optimize the greyscale and gamma response of the display, not to attempt to compensate for how the CMS is set.

From this starting point, we recommend you calibrate the Lookup Table first, using the calibration software to display and measure various levels of white, and making changes to the VideoEq's LUT controls to make adjustments. The LUT is generally adjusted to obtain a smooth, accurate gamma response and to adjust the red, green, and blue levels of the display to achieve the proper D65 white reference.

After the LUT is calibrated, we should have a very nice and even looking greyscale. The CMS adjustments are then done using a similar process, the video source displays primary and secondary colors, the calibration software measures and gives tells how to adjust the controls.

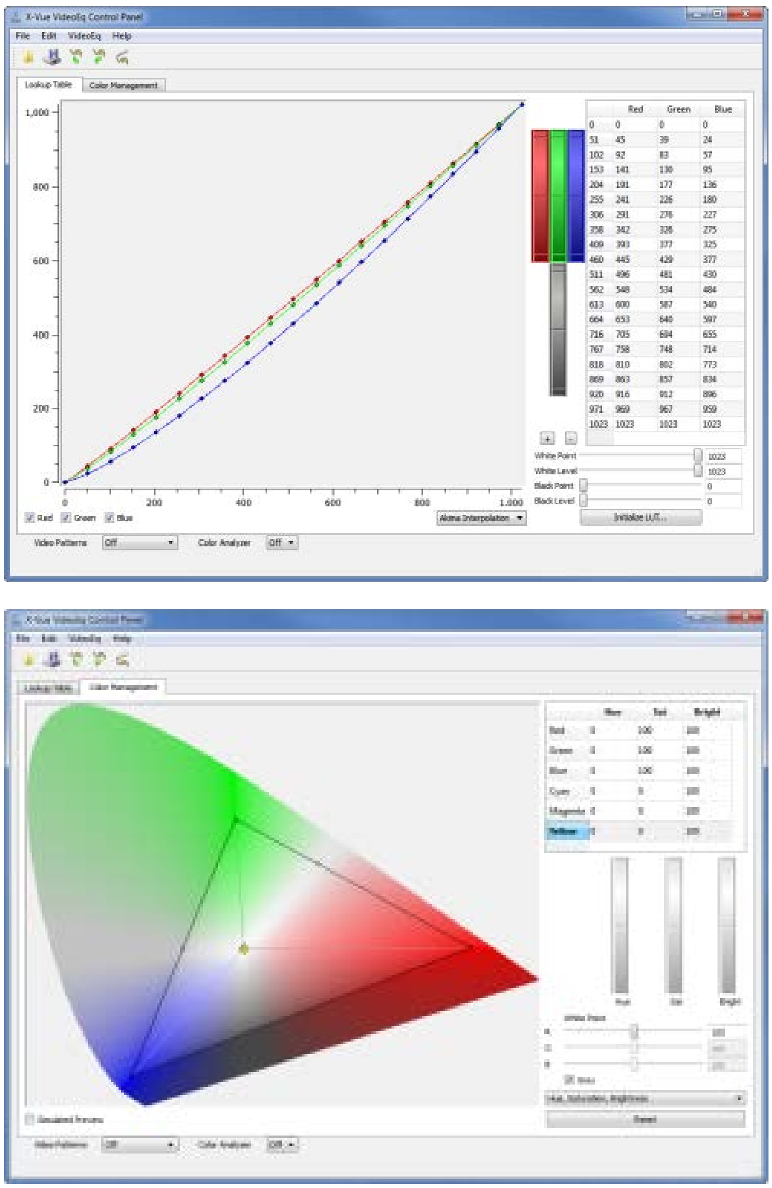

Figure 7 – VideoEq Control Panel Lookup Table and CMS control pages

What Can Go Wrong?

If we have gone through the full calibration process, measured and adjusted everything accurately, we should have a beautiful picture right? Most of the time, yes, but there are still things that can go wrong. Sometimes we will see banding or color distortions or other artifacts that make the picture look strange. Because of the precise nature of the LUT and the CMS, sometimes this will only be apparent on certain programs or channels – those that contain the few colors that are affected by the calibration.

Often in the quest for the perfectly calibrated picture, it is easy to forget that these modern displays still have physical limitations. We may be able to "over drive" certain elements of the display, get a great looking calibration report, but have a bad picture. It is at this point that the "art" of calibration takes over from the "science", and the calibrator has to decide where to sacrifice on the numbers to make the best picture possible.

In our experience, the most often abused control is the CMS brightness. The color standards (Rec709, Rec601, etc) define the luminance levels of each of the color primaries and secondaries in relation to the white point. Often displays are not able to reach this level in either the red or the blue primary colors. The VideoEq will allow the calibrator to increase these levels beyond 100%, which may get closer to the standard, but will sacrifice a smooth even transition from one shade to the next (i.e. introduce posterization and banding).

The easiest way to ensure that the VideoEq is producing accurate and smooth colors is to put up a CIE pattern, or to use the 'VideoEq-Test-Card', which contains specific elements designed to show deficiencies in the color processing. This image is shown in Figure 8. The left edge has a full range greyscale ramp, the citrus fruits show natural saturated orange, red, and green. The CIE diagram shows the smooth transition of the full color spectrum. The children can be used to judge natural looking skin tones. Finally, the weathered wood in the background show natural shades of grey.

Figure 8 - VideoEq Test Card

Conclusion

The VideoEq gives an unparalleled level of control to wanting to get the highest level of performance from a video display. The VideoEq is the perfect solution for many applications. Whether you are a professional needing to match color across large digital signage installations, or a professional photographer using a large flat-panel for your portfolio presentation, or even a home theater enthusiast wanting to get the best color possible.