WHY SHOULD YOU CALIBRATE?

DISPLAY CALIBRATION 101

By Tom Schulte

From the early days of television, the video industry has agreed upon standards for how video signals should be formed and how electronic displays should render those signals into visible images. We've used the NTSC, PAL, SMPTE, and ITU standards committees to establish a common language between video engineers, content creators, content distributors, and display manufacturers. This makes consistent image interchange between local and remote displays a possibility.

Without conformance to those video standards, we wouldn't be able to render the same content onto multiple displays, in multiple locations, producing images with the same visual and emotional impact. We wouldn't be able to exchange electronic images with each other and all enjoy the experience of seeing the very same images that everyone else experiences.

What is Calibration?

Display calibration is the measurement, adjustment, and correction process we use to conform a video display or RGB computer monitor to the relevant display standards, as the display renders standard video signals into visible images. Display calibration makes consistent image interchange between local and remote displays a reality.

Displays that are accurately calibrated insure that:

- We experience image content exactly the way that the content creator intended.
- We perceive photographic images as an accurate rendition of the original scene.
- Luminance relationships are rendered so that we perceive the intended contrast between all details in the dark, mid-tone, and highlight image areas.
- Individual image tones are all individually perceptible, producing a dimensional, lifelike appearance.
- Each image color is rendered with proper hue, saturation, and luminosity.
- Image colors are perceived as being accurate and true to life.
- The same image content rendered on either the same or different technology displays are perceived as matching each other.
- Image accuracy is maintained as a display ages.
- The display performs with the utmost accuracy to which it is capable.

On the other hand, when displays aren't accurately calibrated, one or more of the following conditions may result:

- Photographic images are perceived as not being true to life.
- Colors may be the wrong hue, or look glaring or muted, or be blended together, lacking detail.
- Visible distinction is lost between dark image tones such as shadow details or dark color tones, as they blend together into a blocky darkness.
- Visible distinction is lost between image highlights such as cloud details or other bright image variations, as they blend together into a blocky brightness.
- Detail across the tonal range blends together at some levels, producing flat, lifeless images.
- The same image content rendered on different displays is seen as having distinctly different contrast, detail, or coloration.

- Image rendition qualities are seen to change as a display ages.

Who Should Calibrate?

Electronic displays are used throughout all segments of society, from entertainment, to advertising, business, manufacturing, transportation, medicine, security, and many more. Display calibration is the only way to insure that images shown on screen are accurate and faithful to intent. Calibration is essential for anyone who relies on the rendering accuracy of their displays.

Following are some ideas on why display calibration probably matters to you, no matter how you might use electronic displays in your professional, business and personal life.

- **Movie Production - On Set**

  The on-set Digital Imaging Technician (DIT) collaborates with the director of photography and cinematographer on work-flow, camera settings, signal integrity and digital image manipulation. The DIT wants to keep their trust as he works to achieve the cinematography creative goals and the highest image quality. He can do that effectively only if his on-set monitors are calibrated for accurate image rendering.

- **Movie Production - Digital Dailies/Rushes**

  The DIT or a post professional is responsible for creating digital dailies from each day's shot footage, which the director and senior production personnel view in order to make logistic and creative decisions. Imaging mistakes made at this point can have significant and expensive consequences on future production.

  An accurately calibrated dailies display or projector insures that inaccurate image rendering doesn't mislead the production team and precipitate such mistakes.

- **Movie Production - Color Correction**

  When a movie's scenes have all been shot and edited together, a post-production colorist applies color correction to each movie frame, as guided by the director. The colorist views each frame image on a reference monitor to guide their decisions to match colors from frame to frame and to apply creative tonal and color effects.

  For the colorist, reputation and rework are on the line if they can't trust their monitor. And, imagine the difficulty that an inaccurate reference monitor creates for movie directors and production companies if their creative intent can't be faithfully conveyed to their viewing audience.

- **Broadcast and Cable**

  Video editing suites at broadcast and cable studios have much the same situation as movie post-production suites. They edit commercial and live news footage, then color correct the final footage. The reference monitors they use to guide their color grading decisions determine the "look" of their final material to all their viewers. Broadcasters and cable networks don't want the satisfaction of their advertising clients and regular viewers to be spoiled by poorly calibrated reference monitors.

- **Photography**

  Professional photographers also color correct their photographic images, on a computer monitor that they trust to perform with reference quality. It is absolutely necessary that they be able to trust that the look of the images on their monitor screen is what their clients will see in their delivered work. An accurately calibrated monitor gives photographers creative confidence and helps build a satisfied client list.

- **Graphic Design**

  Graphic designers are always concerned that, after they've designed a layout and either print it locally or send it out to print, the printed result won't match what they designed on their monitor screen. Mismatched output leads to miscommunication, rework, delays, client

dissatisfaction, and reduced revenue. Is it the monitor's fault, their fault, or the printer's fault?

Creating a monitor calibration profile for each of their target output devices, along with selecting the proper ICC profile for their local printer, allows them to achieve consistency with their local printer and the web. They can then be confident that any remaining print shop problems are not their fault.

- **Product Design**

  When designing product containers, packages and cases, industrial product designers pay great attention to the color, texture and gloss of the product surfaces. They need to have confidence that when the product design is sent out for prototyping and production the final product will match their design intent, as designed and visualized on their electronic displays.

  Inaccurate display rendering leads to rework, delays, cost overruns and missed deadlines, all deadly in the business world. Designers can't tolerate mismatched or inaccurate monitors; each monitor needs to accurately render images to the relevant standard and match other monitors on their desktop, in the design facility, and in partner facilities.

- **AV Integration**

  Professional integrators install every sort of electronic display imaginable for their clients, ranging from outdoor video walls to video conferencing monitors and projectors, house of worship projectors, computer design stations, entertainment TVs, indoor video display walls and more.

  In each case, the quality of the final image(s) is a large part of how their clients judge the installation. Do some displays not match each other, are the colors wrong, is there poor contrast, do the images look flat, lacking detail? Integrators on tight schedules can't afford rework time trying to fix clients' poor job satisfaction. They need every display performing to the best of its ability when each site is commissioned, producing high client satisfaction and minimum callbacks.

- **Geospatial**

  Geospatial intelligence, GEOINT, GeoIntel, or GSI involves the display and analysis of satellite imagery, often performed across multiple computer monitors. This may be for land usage, climate, military, topographic, wildlife, surveying, or disaster analysis. In each case, maximum visual information needs to be accurately interpreted from each grayscale, true color, or false color image.

  Each computer monitor used to render these images needs to produce an equally-perceptible step in the rendered image's luminance level for each step in the digital image's signal level. A special Equal Probability of Detection (EPD) luminance response function has been defined by the U.S. National Geospatial Intelligence Agency to allow monitors to be calibrated for maximum information perception. A monitor that conforms to that function ensures that even subtle variations in image tones or colors can be visually detected.

- **Medical Imaging**

  Whether it be radiology, mammography, nuclear, pathological microscopy, dental, or veterinary imaging, the technical goal for medical imaging is much the same as with geospatial imaging. Each signal step in a scanned medical image needs to produce an equally-perceptible step in the rendered image's luminance level. A special Digital Imaging and Communications in Medicine (DICOM) luminance response function (L* for Europe) has been defined to allow medical monitors to be consistently calibrated for optimum diagnostic capability. Inaccurate medical display rendering can result in compromised diagnostic outcomes.

  Medical physicists, radiologists, and biomedical engineers responsible for the diagnostic and clinical review displays used to view these medical images cannot accept poor display

performance, on medical, professional, and legal liability grounds. These medical imaging displays must be accurately calibrated.

- **Home AV**

  We want all the images that we view on our home displays to be rendered accurately, including movies, videos, web content and family photos. We want all of our display screens to show 'pretty pictures,' including our TVs, laptop screens, computer monitors, tablets, and pads.

  Movie images should be an accurate rendition of what the directors approved on their reference monitors in the film studios. Web content should be detailed and accurately colored.

  Family photos are always important to us, whether we shoot photos with a cell phone or with a DSLR. When we review our photos with others on our laptop screen or on our big-screen TV, we want to see vibrant, life-like photos; not muted, discolored, boring, flat images. Calibrating all our home displays can give us renewed enjoyment from our AV equipment investment.

- **Display Manufacturing**

  Manufacturers of electronic displays have always wanted to sell displays that conform closely to established industry standards and produce very accurate images, but they've been caught in a marketing conundrum. To succeed and prosper in the marketplace, they also need to distinguish their displays from those of their competitors.

  From many market studies, display manufacturers know that brighter looking displays are appealing to buyers, when seen next to other displays. Since the beginning of the TV age, display manufacturers have developed brightness-enhancement "features," especially to distinguish their consumer models. A default Vivid picture mode may inaccurately skew the grayscale background toward blue, which appears brighter to the human eye. It may also apply excessive signal path gain (Contrast), pushing more of the rendered image to the display's maximum luminance limit. It often sets the display's luminance response to a very low gamma value, producing artificially high luminance for mid-tone image values. And, it may set the image black level artificially low to enhance perceived contrast and thus, perceived brightness.

  These consumer-level displays often have a very high native accuracy capability, but, to realize that full accuracy potential, they need to have any brightness-enhancement features disabled and have professional level calibration applied. Many high end consumer displays have even been used, in a fully-calibrated mode, as substitutes for more expensive reference-quality displays.

  The reference-quality displays that a manufacturer targets to professional users usually have very few of the brightness enhancement features of consumer models, other than possibly a slightly over-blue grayscale background in the default picture mode. Also, many manufacturers are now including 3D corrective lookup tables (LUTs) within their better and best quality displays. These displays with internal 3D LUTs, which allow more precise luminance and color correction at all points within the display's color space, are seen by professional display users as being of higher quality.

  There are also displays at the high end of the quality spectrum that the manufacturers target to industries that require strict conformance to standards. Displays are available with one or more preset calibration modes for DICOM, EPD, Rec.709, sRGB, and wide gamut Adobe RGB (the modes are often preset from an average, not individually calibrated). These displays are often able to be switched between a number of preset calibration modes. In every case, custom calibration of a desired mode, especially with a 3D LUT, yields the most accurate display performance.

How Does Calibration Work?

Display calibration uses specialized calibration software to measure a display's performance with a color meter and either adjust the display controls and/or create calibration data to correct the display's luminance and color performance. A display is calibrated to conform its performance to a relevant set of display standards, or target values (i.e. gamma, white point color, color gamut). These standards are selected to match those that were used to create the image content that will be viewed (e.g. web content, movie content, photos, medical radiology images).

Calibration Adjustments

During display calibration, adjustments are made to the following parameters of a display's performance to conform the display to the relevant set of display standards:

- Dynamic range – the range between a display's white luminance and black luminance levels.
- Gamma – a display's luminance levels at signal levels between white and black.
- White point color (white balance) – the color of white.
- White balance/grayscale tracking – the color of shades of gray between white and black.
- Color gamut – the display's colorspace volume, as determined by the primary colors created by the display.

For video displays, ranging from consumer TVs to Grade 1 reference monitors, the display's picture menu controls, RGB white balance controls, and color gamut (CMS) controls are adjusted to best conform the display's performance to the selected set of display standards.

For RGB computer monitors, ranging from laptop screens to large desktop monitors or projectors, the monitor's picture menu controls and RGB white balance controls (if available) are usually optimized to best conform the monitor's performance to the selected set of display standards.

Additional Correction Data

After a display's internal controls have been optimized for best conformance to the selected set of display standards, additional correction data can be created to correct rendering problems that aren't addressed or fully corrected with the display's internal controls.

For an RGB computer monitor, a 1D LUT can be written to the computer graphics adapter to correct any linearity errors in the monitor's white balance tracking. And, an ICC profile can be created to transfer data about the display's primary color errors to ICC-aware applications (PC) or to the OS X operating system (Mac), which then corrects the RGB signals sent to the monitor.

If the video display or RGB computer monitor is capable of loading an internal 3D corrective LUT, the display's color space can be profiled to create LUT correction data. The 3D LUT can then be loaded directly into the display memory.

If a hardware LUT processor is present in the signal path to the video display or RGB computer monitor, the 3D LUT can be loaded into the in-line LUT processor to pre-correct the signal going to the display.

If the video display or RGB computer monitor is being driven from imaging software (e.g. Resolve, Scratch, etc.), the 3D LUT can be loaded into the imaging software to pre-correct the signal sent to the display.

Why 3D LUTs?

Even after all the controls available on a video display or RGB computer monitor have been optimized, every display normally has a number of remaining rendering errors. Modern digital displays have nonlinear errors, especially, that are not well corrected without the complex correction abilities of 3D LUTs.

A 3D lookup table of correction data corrects linear and nonlinear rendering errors for every color in a display's color space. The 3D LUT corrects all gamma, white balance, grayscale tracking, RGB crosstalk, color decoding, and color gamut errors.

However, profiling a display to obtain the performance information needed to create a 3D

corrective LUT has been a long, complicated process. And, legacy 3D LUT profiling systems measured a static set of profile points. This placed more points than were needed in linear areas of a display's color gamut and not enough points in the nonlinear areas. That allowed any display nonlinearities to skew the accuracy of the calculated and linear interpolated LUT data.

CalMAN 3D LUTs

The CalMAN Dynamic Profiling™ 3D LUT display calibration system, with a new display profiling and 3D LUT targeting engine, more effectively corrects display rendering errors than any other calibration system. The Dynamic Profiling system is now more efficient and user friendly with Intelligent Resolution Profiling™ (IRP) and Lightning LUT.

IRP produces the highest accuracy correction for nonlinear displays within a user-selectable calibration time. It uses Dynamic Linearity Correction to allocate a majority of the profile points to the nonlinear areas of the display's color space, for maximum effectiveness within the given time limit. You press a single AutoCube calibration button and come back shortly to a highly accurate, fully optimized 3D corrective LUT.

Intelligent Resolution Profiling usually creates the desired accuracy for nonlinear displays in only two to three hours. Lightning LUT produces high accuracy correction for moderately linear displays in just five minutes!

And, with 3D LUT Retargeting, you can retarget your display profile to a new color space in just minutes, without performing additional display measurements.

For more detailed information about display profiling and calibration with 3D LUTs, see Display Profiling Solutions: A Report on 3D LUT Calibration.

Trusted Worldwide

CalMAN calibration software is available for displays used in every industry, for calibrating all displays, including Grade 1 reference monitors, RGB computer monitors, medical imaging displays, consumer televisions, home theater projectors, and more.

The following companies use CalMAN calibration software and trust CalMAN calibration solutions:

- Technicolor
- Walt Disney Pictures
- Dolby
- NBC
- CNN
- YouTube
- Netflix
- Apple
- Microsoft
- JVC
- Panasonic
- CNET

Whether you need a reference display as a visual measuring instrument, a dependable business imaging display, or an enjoyable entertainment display, CalMAN calibration and CalMAN 3D LUTs insure that your display performs with the utmost accuracy to which it is capable.

If you are interested in calibrating your display or monitor, please contact our customer service team. They are ready to match the best calibration solutions to your unique display application.

About SpectraCal:

SpectraCal specializes in the tools and training necessary to achieve images representative of the content creator's intent for environments from low to high ambient light while achieving the colorimetry, contrast, and dynamic range necessary for the image to have the proper impact on the viewer.

SpectraCal CalMAN software was developed to support the display calibrator in the step by step process of screen optimization. The foundation of screen optimization through display calibration is to understand the elements in a display that require adjustment and how each element inter-relates to the others. From its inception, CalMAN has earned rave reviews and has become the preeminent display calibration software package on the market, compatible with virtually all color meters available today. As display technology evolves, CalMAN will continue to provide the first choice for display calibration solutions.

More Information:

For more information on CalMAN professional quality solutions for your displays:

Visit: http://studio.spectracal.com/store/calman-software/calman-studio.html,

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Tom Schulte is Product Development Manager at SpectraCal. Tom has extensive experience in electronic systems test, calibration and service, as well as electronics test instrument design and usage and has authored numerous technical white papers. Tom was previously an Application Engineer at Sencore for over twenty years, where he was involved in video, audio, and RF test instrument design, plus training and support for electronic test equipment users.