True Hardware Calibration

– Key factors for quality calibration and validation of high-end monitors

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Monitor calibration is not only extremely important for printing, but for any imaging professionals, including photographers and designers, who share their work online and in print. When performing professional image retouching and soft proofing, it is key to calibrate the monitor to a set standard. The standard used depends on the type of applications at hand. Regardless of the standard you prefer, successful calibration validation is critical to ensure that any variations in color, brightness, gamma and grey balance are minimal and stay within the tolerances you have set for your application type.

Introduction

It is widely accepted that quality calibration needs to be done using what is often referred to as a "hardware calibration". What is far from accepted is what such hardware calibration consists of. In this white paper, we will not only clarify what hardware calibration really entails, but also introduce and explain other key parameters that should be considered in high-end monitors and calibration software to be regarded as a professional, high-end solutions.

What is hardware calibration and why is it important?

There are many ways to calibrate a monitor and many different solutions on the market. In the case of true hardware calibration, a measuring device is used to measure color output from a monitor and adjust the monitor's output signal through a dedicated calibration software that can communicate and control the monitor electronics. Monitor adjustments done visually and without a measuring device is not performing hardware calibration. While there is widespread misunderstanding that hardware calibration means using a hardware measuring device, this alone does not actually qualify as true hardware calibration. In most cases, the calibration software only adjusts the signal to the graphics card, and sometimes even requires additional manual adjustments by the user through the OSD (On Screen Display menu). This is how most calibration solutions on the market operate.

True hardware calibration occurs when the calibration software can adjust the signal inside the monitor to conform to the desired setting for brightness, white point, blackpoint, color gamut, greyscale and gamma. These signal adjustments should be done "hands free" without manual intervention by the user or operator! For this to work, the calibration software needs to be tightly integrated with the monitor hardware and is typically dedicated to the monitor brand and model type. This type of high quality calibration is rare on the market, provided by only a handful of manufacturers. Only true hardware calibration can offer the precise adjustments and control of the image signal needed for professional, high-end image retouching and soft proofing. Needless to say, this type of calibration naturally puts a higher demand on the quality of the monitor itself and how the monitor is connected.

When performing true hardware calibration, the legacy VGA connection with an 8-bit analogue data communication will not suffice. With VGA connections, at least 1 bit of data, possibly two, is typically lost; therefore you will not have the theoretical 8 bit per channel bit depth in practice. Therefore, although you may hope to have 256 shades of grey per channel RGB (theoretically 24 bit color data and a color gamut of around 16.7 million colors), a monitor connected through a VGA cable cannot provide this. A true hardware calibration will need a 10 or 12-bit data connection, which is provided by newer connections types like DVI, HDMI and Display Port. Aside from communicating the image signal at high resolution and bit depth through the connection cable, additional data connections are needed to control monitor settings and adjustments. These connectivity requirements can be achieved through the DVI, HDMI or Display Port cable at reduced data speeds, or better yet, through a dedicated USB cable. A 10 or 12-bit digital signal will render a high enough calibration to ensure optimized results and use of the monitor to its full potential.

Which standard to calibrate to?

There are two main uses for high-end monitors: previewing/retouching photographs, as well as previewing and soft proofing images or pages as they will appear in print. A photographer may use the monitor for both of these applications, and will typically calibrate a monitor to a well-known color gamut such as Adobe RGB. Other standard RGB color gamuts, like sRGB, exist but are quite a bit smaller than Adobe RGB and are not suitable for high-end photography. There are also larger color gamuts than Adobe RGB that may be considered for RGB images and RAW files, but for general purposes the Adobe RGB is large enough to preserve the original quality of a digital image taken by a professional digital camera. The Adobe RGB gamut is quite close to, and is in fact slightly larger than, those of wide-gamut inkjet printers used for high-end photo realistic print production. This makes the Adobe RGB color space a very popular choice for professional photographers and an important benchmark to reach for professional monitors.

Soft proofing is traditionally done at prepress companies or by publishers or designers. Here, instead of viewing the image in RGB, the monitor is asked to apply the output ICC profile to the image data and preview (soft proof) the page or image as it would appear printed in CMYK. This color conversion takes place in the software used with the help of the color management system residing in the computer's operating system, be it MS Windows or Apple Mac OSX. To achieve an optimum result in those two typical applications, the calibration of the monitor needs to be tailored to slightly different settings. This is because different standards use different references in regards to white point, and to some extent at what brightness the monitor should be calibrated to.

The Adobe RGB color space uses a white point of 6600K, where K stands for Kelvin and is the unit for the nuance of white. There is a range of nuances of white light, ranging from very reddish candlelight to reddish-yellow light bulbs, up to a fairly bluish ("cold") white light from certain types of fluoresce tubes. The term "standard daylight" is sometimes understood as a natural light source of 6500K, but in reality, natural light sources vary, even in the appearance of sunlight. Instead, standard daylight should be understood as a series of artificial light sources which conform more or less to a specification. It is not only the white point that is specified in, for example, CIE Standard Illuminant D65; the spectral distribution of the wavelengths of the light source should follow a set ideal curve, and the white point should be as close as possible to 6500K. However, there are other standards for daylight illuminant, such as D50 which is used as reference in the ISO standards for print production.

So while you may prefer to calibrate to D65 which has a white point close to the Adobe RGB 6600K for photo previewing and retouching, it is also common to calibrate to D50 with a 5000K white point for soft proofing. With true hardware calibration, this is very easy to do.

Other ISO standards which may also come into play are ISO 3664 for viewing booths, ISO 12646 for graphic arts proofing monitors, and finally the ISO 12647 series for printing standards. A monitor needs to have a wide enough color gamut to be able to reproduce the colors in the reference color gamut, whether Adobe RGB or, for example, ISO 12647-2 offset printing on high-quality coated paper. The calibration software used for hardware calibration should be able to not only set up the calibration for those types of applications, but also perform calibration validation to check that the specifications are met within the tolerances allowed.

Other demands of a high-end retouching and soft proofing monitors

We have concluded that true hardware calibration is needed when performing very precise and accurate calibrations, and that the monitor must have a large enough gamut to show the colors correctly. To properly view a photograph saved as Adobe RGB, you must naturally view it on a monitor which can reproduce the whole Adobe RGB gamut. While the number of unique color combinations in RGB is 16.7 million colors in a 24-bit image file (8 bits per channel RGB), the human eye cannot actually tell very minor color differences apart. The threshold for what we humans can differentiate between two colors is typically stated to be ΔE 1 (Delta E); so when analyzing digital images and only counting the colors with at least a ΔE difference of 1, Adobe RGB contains about 1.2 million different colors. Consequently, a high-end monitor should to be able to reproduce 1.2 million or more colors to offer a true presentation of the image saved in Adobe RGB.

For soft proofing of pages or images which will be printed with the CMYK color model, the calculation is similar with small differences. The color set in CMYK is different than when using RGB, but when we analyze the ICC profile used in modern color management, we see that the color gamut of a print according to ISO 12647-2 on coated paper, using a litho offset press, is "only" around 400 000 colors. But the primary colors, or inks, in CMYK are Cyan, Magenta, Yellow and Black (called Key color). The primary color model of a monitor is RGB, which is Red, Green and Blue. When a monitor reproduces the color Cyan, it needs to mix Green and Blue. Therefore, in the additive RGB color system, the CMY colors are secondary colors. While the primary RGB colors are very vivid, the secondary colors are, by nature, less so, and the RGB monitor therefore struggles a bit when trying to reproduce the pure CMY colors. The subtractive CMYK color system has pure CMY primary colors, but it too struggles when recreating the secondary colors Red (created with Magenta and Yellow), Green (created with Cyan and Yellow) and Blue (created withCyan and Magenta). Black ink is only used for text and to enhance the contrast in the images, as well as darkening saturated colors.

It turns out that the gamut for a monitor to soft proof printed pages or images as they appear when printed in offset on coated paper using CMYK is roughly equivalent to the gamut of Adobe RGB. Any monitor that has a smaller gamut than Adobe RGB is not likely to be able to render the CMYK colors accurately enough.

Brightness

While color gamut is critical, the monitor also needs to be sufficiently bright to come close to that of a professional viewing booth. A viewing booth should conform to the ISO standard 3664 which requires a very high brightness in the range of 2000 lux. For a monitor, whose brightness is measured in Candela per square meters (Cd/m_2), this would be equivalent to 700 Cd/m_2! But the ISO 3364 standard also suggests a much lower brightness setting if the print or proof is to be compared side-by-side with an image viewed on a monitor (soft proofing). This soft proofing setting is 600 lux and is similar to what is recommended for the brightness in an office environment. In practice, this means that the monitor should have enough brightness to be used in the ambient light equivalent of normal office lighting. While most modern monitors can achieve brightness of 300 Cd/m2 or higher, having a monitor set to 300 Cd/m2 appears very, very bright, and will create eye strain over a day of use. Monitor brightness of 120-160 Cd/m_2 should be enough to match a viewing booth setting of 600 lux.

Uniformity

If a monitor has a large enough color gamut and can produce a high enough brightness, the following item to check is that the tone values are reproduced accurately enough across the surface of the screen. This uniformity is important both when performing image retouching and when using the monitor for soft proofing. A professional calibration software should be able to check for tone variation which should ideally not exceed 10% over the entire display surface.

Low viewing angle sensitivity

The final parameter to check on a monitor for high-end imaging is its sensitivity to a user's viewing angle. If the colors or shades of grey change in appearance when moving ones head up or down, left or right, then the monitor is sensitive to the viewing angle. This is difficult to check through calibration software, but can be easily detected by comparing different sample images at different viewing angles.

Currently, one panel technology stands above others in offering a desired low viewing angle sensitivity: IPS (In-Plane Switching) technology. IPS LCD monitors offer color consistency and accuracy from wider viewing angles and should be considered when selecting monitors.

A monitor hood

Last but not least, a professional monitor for quality image retouching and soft proofing should be equipped with a monitor hood to mitigate the effects of ambient lighting, and reduce reflections on the screen's surface.

When using a monitor in an office environment, stray light will always cause reflections, thereby reducing the display contrast. Although you can always buy an after-market monitor hood, any professional imaging monitor vendor should have this as a readily available option, if not already included in the package.

Conclusion

For professionals working in photography and design the absence of hardware calibration may mean you're not seeing everything in the image. Color casts and contrast biases will affect the quality of your work without you even knowing it. Beautiful sunsets and smooth horizons may appear pale with gradient streaks or have improper exposure levels. Hardware calibration is essential to ensure that the images you are processing in Adobe Photoshop or Lightroom are consistent to what people will see online and to what is printed afterwards.

The natural question then is whether high-end monitors from BenQ can meet all the given criteria for true hardware calibration and professional imaging usage? The answer is quite simply "Yes". Through the dedicated Palette Master calibration software, true hardware calibration can be done with one of its supported measuring devices on the market. A USB cable is connected between the BenQ monitor and the computer . The monitor settings and data control is communicated through this USB cable, while the video signal is transmitted through the video cable of choice (such as DVI, HDMI, or DisplayPort). BenQ professional monitors and hardware calibration solutions allow imaging professionals and enthusiasts put forward their best work possible.

CAPTIONS

For true hardware calibration, the calibration software must be able to adjust all monitor settings through a dedicated USB cable or over DVI or Display Port.

Different light sources have different spectral distributions, which includes differing nuances of "white". The diagram to the left shows the spectral distribution of D50 with a standard daylight white point of 5000K. To the right, the D65 standard daylight has a white point of 6500K.

Hardware calibration means, among other things, using a measuring device in the process. It is also important to use a monitor hood to cut out ambient light and reduce light reflections off the screen surface.