

Monitor Calibration: Theory and Practice for the Fine Arts

Monitor calibration adjusts three parameters:

Colour Temperature • Tone Reproduction • Luminance

Each parameter needs to be referred to the conditions of use, for example whether the image will be edited on the monitor independent of printed output (ISO 3664:2000 Viewing conditions - Graphic technology and photography), or compared to printed output (ISO 12646:2008 Graphic technology - Displays for colour proofing - Characteristics and viewing conditions). The following table summarises some of the main characteristics of each ISO standard .

	ISO 3664	ISO 12646
Monitor White Point	CIE D65	CIE D50
Monitor White Luminance	75cd/m2 to 100cd/m2	80cd/m2 to 120cd/m2
Ambient Light White Point	CIE D50 (5000°K or less)	CIE D50 (5000°K or less)
Ambient Light Editing Areas	64 to 32 lux (or lower)	32 lux (or lower)
Ambient Light Proofing Areas	1,500 to 2,500 lux	1,500 to 2,500 lux
Ambient Light Extraneous	Baffle from view all windows, light sources, etc	Baffle from view all windows, light sources, etc
Ambient Light Glare	No reflections on monitor	No reflections on monitor
Environmental Surfaces	Colour-neutral surfaces: Walls 60% reflectance or less	Colour-neutral surfaces: Walls 60% reflectance or less

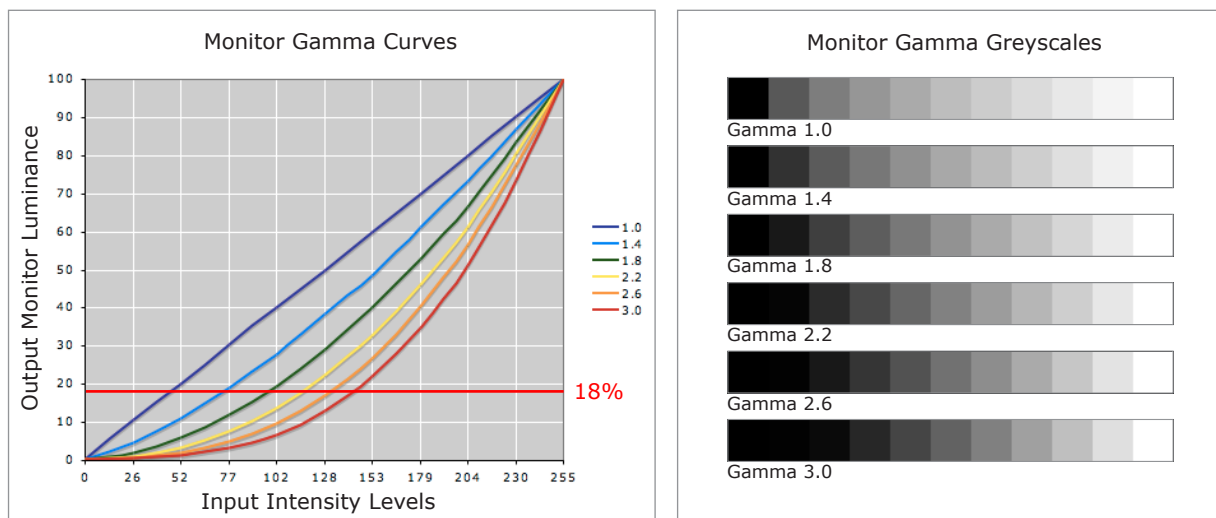
Colour Temperature

When a monitor to print match is not required, begin by calibrating the monitor to a colour temperature of 6500°K (ISO 3664). Once calibrated, fill the screen with a greyscale image and if required adjust the monitor's colour temperature until the greyscale image appears neutral. That is, neither too cool (cyan-blue) or too warm (red-yellow) relative to the surrounding environment.

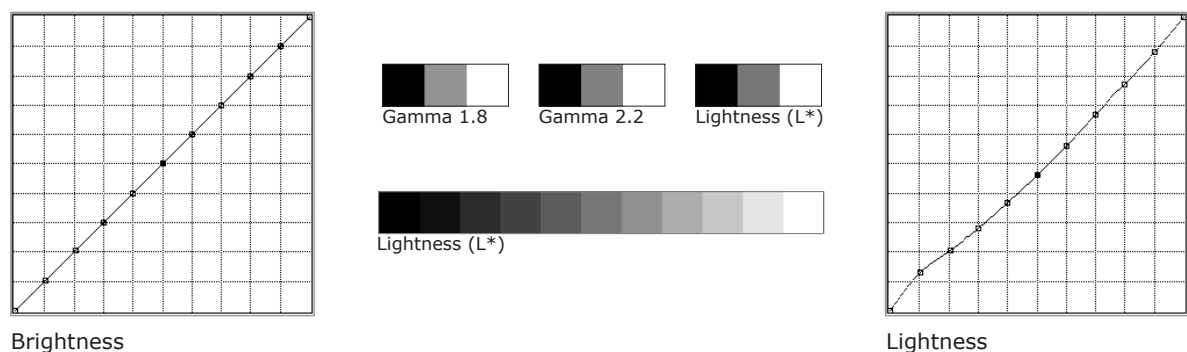
If the monitor must simulate printed output, begin by calibrating to 5000°K (ISO 12646) and then adjust its colour temperature to visually match the print's white point (paper white). A Solux 4700°K lamp (www.solux.net) usually provides a close visual match to a 5000°K monitor white point. Fluorescent tubes manufactured for soft proofing (www.gtilite.com & www.just-normlicht.com) with a correlated colour temperature of 5000°K usually provide a close visual match to a monitor calibrated between 5500°K and 6000°K. The ambient lighting and surrounding environment will also effect the appearance of the screen, but in all cases a greyscale image, whether a soft proof or a print, should appear neutral relative to its environment.

Tone Reproduction

Gamma correction is important for the satisfactory display of an image on a monitor with non-colour managed content and applications. For example, a PC interface is designed to be viewed at a gamma of 2.2, while a Macintosh interface is designed to be viewed at a gamma of 1.8. On the other hand, colour managed applications like Adobe Photoshop™ will automatically transform image data to the current monitor profile ensuring correct values are displayed on screen irrespective of the monitor's gamma. The monitor's gamma setting therefore only alters the appearance of non-colour managed content and applications, and does not alter the monitor's white or black points, only the relative brightness of the mid tones on screen. The following chart illustrates a series of monitor gamma curves and their resulting non-colour managed grey scales.



An alternative approach to a monitor's tone reproduction calibrates its tonal response to Lightness (L^*) which is the human perception of relative brightness. The calibrated monitor then represents equal intervals as equal brightness steps, rendering it linear with respect to the human visual system. Note that some monitor calibration software does not support L^* calibration.



Another approach for colour managed applications selects the same gamma as the working space gamma. This will minimise any loss of image levels (reduced bit depth) during the video card LUT or tone curve transformation from the working space profile to the monitor profile. Therefore if you work with ProPhoto RGB, Apple RGB or ColorMatch RGB calibrate your monitor to a gamma of 1.8, or gamma 2.2 if you work with Adobe RGB or sRGB, or L^* if you work with ECI RGB v2. If you work with a variety of colour spaces, and/or on both Mac and PCs, and/or with colour managed and non-colour managed applications, a monitor gamma of 2.2 is a reasonable compromise.

Luminance

Three interrelated factors combine to define the required monitor luminance levels:

White Luminance • Black Luminance • Contrast Ratio

The difference between a monitor's white luminance and black luminance equals its contrast ratio. Increasing white luminance does not vary the minimum black luminance of an LCD monitor. Therefore the brighter the monitor's white luminance the higher its contrast ratio. Controlling the black luminance level is important for precisely adjusting the monitor's contrast and adapting it to specific output conditions. This is particularly critical when the aim is to simulate printed output, that is to 'soft proof' (predict) on the monitor the appearance of the printed image.

White Luminance:

Begin by calibrating the monitor to a white luminance of 100.0 cd/m², then compare a 'colour managed test print under your standard viewing light' with its soft proofed image on the monitor. Use an image containing large areas of shadow detail in this evaluation. If the shadows appear more visible and detailed in the monitor's soft proof than in the print, the monitor's white luminance will need to be lowered, or the print viewing light's brightness increased. In practice the monitor's white luminance will usually fall between 80.0 cd/m² and 110.0 cd./m² when referenced to the printed image - depending on the ambient brightness of the working environment and the print viewing conditions. A white luminance of 100.0 cd/m² also broadly equates to a print viewing illuminance of 400 lux.

Black Luminance:

Begin by calibrating the monitor's black luminance to 0.40cd/m². Spectrophotometers and colorimeters used in monitor calibration are less accurate at measuring black luminance compared with measuring white luminance. Aim for a final black luminance between 0.3 cd/m² and 0.5 cd/m² in the standard working environment. On-screen flare will dramatically effect the appearance of the black luminance, and its soft proofed relationship to an actual print. Therefore care must be taken to exclude all direct reflections on the screen and reduce flare by keeping ambient light levels low.

Contrast Ratio:

Calibrating the monitor's white luminance to 100.0 cd/m² and black luminance to 0.4 cd/m² results in a monitor contrast ratio of approximately 1:250. This is ideal for soft proofing because it simulates a rich glossy print's density range of approximately D2.40 (Dmax 2.50 - Dmin 0.10) or 8 EV ($2.40 \div 0.3 = 8$) which equals a contrast ratio of $1:2^8 = 1:256$.

Not all monitor calibration/profiling applications enable the manual adjustment of the monitor's black luminance, but most nevertheless report what it is as a result of the calibration sequence. Note this value and adjust the white luminance and re-calibrate to achieve approximately a 1:250 monitor contrast ratio. Raising the monitor white luminance above 100cd/m² and thereby also increasing its contrast will only be required to counteract the contrast lowering effect of screen flare due to a brighter than standard working environment, and/or a brighter than standard black luminance. In practice a white luminance greater than 140.0 cd/m² or a contrast ratio greater than 1:250 will normally not be required in fine art photography applications.

Monitors however can be calibrated for different tasks to predict different output conditions. Defining those tasks and then adapting the monitor to them is fundamental to the calibration process.