

# Soft-Proofing Theory

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## Introduction:

Soft-proofing refers to a monitor displaying another condition. Typically this is the simulation of the displayed image as if it was a print. Therefore a soft-proof is not a hard-proof (print), but the (soft or virtual) simulation of how the image might appear when printed. However very accurate soft-proofing is not as simple or straight forward as it might at first appear. This explains why a common refrain from inexperienced digital photographers is “but my print does not match my screen.” Common misconceptions are that any monitor is capable of accurate soft-proofing, underestimating the influence of the print viewing conditions on the appearance of the print; and overlooking the influence of the viewing environment on the appearance of the screen image and our adaptation to it.

Soft-proofing can be a critical technique for improving efficiency and productivity in any workflow where the displayed image must also be rendered and evaluated as a print. While it is possible to achieve a satisfactory correlation between the printed image and its screen image, many factors influence and limit this outcome.

## Physical and cognitive factors:

There are numerous dimensions to our viewing, reception and appreciation of a printed image. A print is both a physical object subject to the constraints under which it is observed, and a representation of something else. While the subject is present, the object it refers to is usually absent. Two completely different colour systems, additive (screen) and subtractive (print) also have to be correlated. There are at least eleven physical properties of a print, which comprise various paper and image attributes:

- The colour and brightness of the paper
- The texture of the paper
- The size of the paper
- The weight (gsm) of the paper
- The opacity of the paper
- The surface of the paper (gloss, lustre, matte).
- The optical brighteners and/or shading agents in the paper
- The size of the image
- The dynamic scale (Dmax and Dmin) of the image
- The spectral properties of the colourants in the image.
- The resolution of the image

There are also environmental and cognitive factors effecting the reception and interpretation of the displayed and printed images, such as:

- The spectral distribution of the ambient and viewing lights.
- The correlated colour temperature of the print viewing light.
- The luminance and quality (focused or diffused) of the print viewing light.
- The influence of the surrounding surfaces, ambient light sources and colour palettes.
- The level of flare in the viewing system.

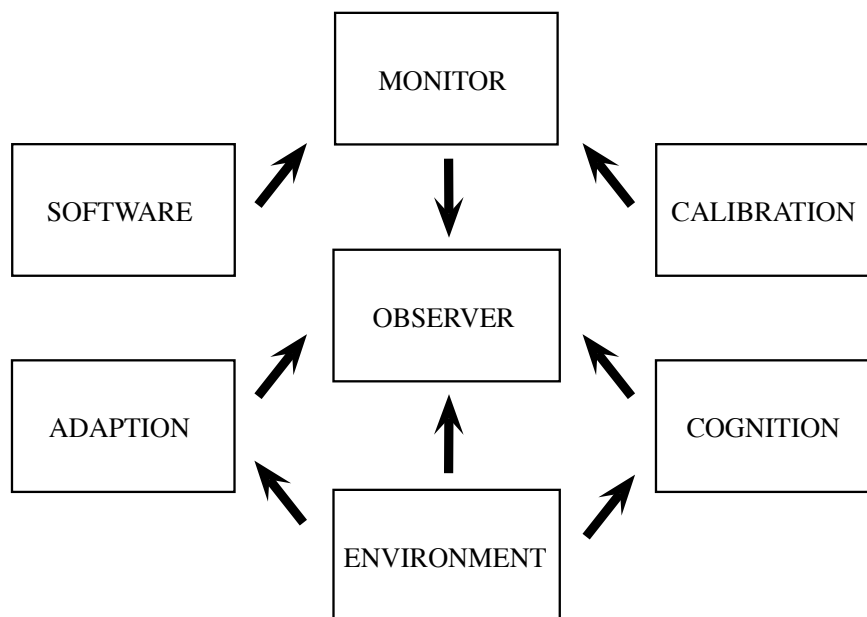
## Soft-Proofing Theory:

- The adaptation of the observer to the viewing environment.
- The visual history and experience of the observer.
- The expectation of the observer.

The physical properties of the monitor, its hardware and software are additional factors to be considered, including:

- The spectral distribution of the monitor's light source.
- The correlated colour temperature (white point) of the screen.
- The dynamic range (Dmax and Dmin) of the screen.
- The luminance of the screen.
- The reflections and flare on the screen.
- The surface treatment (glossy, coated, matte) of the screen.
- The resolution of the screen.
- The size of the display area of the screen.
- The application that is displaying the image on the screen.
- The quality (bit depth) of the video signal being sent to the screen.

### Summary of the factors influencing the accuracy of soft-proofing:

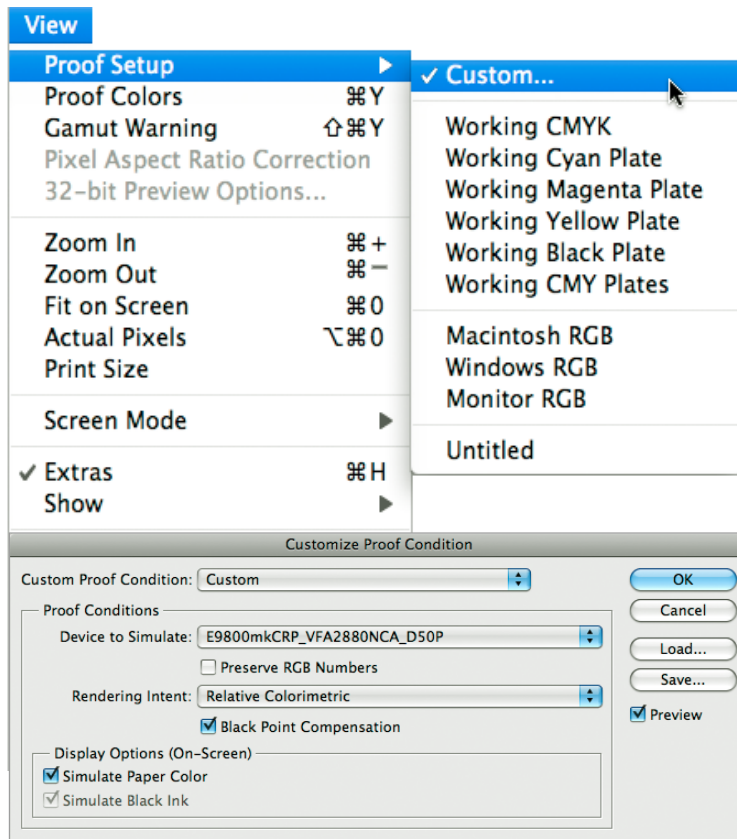


### What can and can't be soft-proofed?

The reality is that soft-proofing can not 'represent' all of the properties and attributes involved in our experience of a print. For example, unless the image is physically smaller than the screen and has a resolution equal to or less than the screen, the print's scale and acutance can not be soft-proofed. What soft-proofing can do is 'represent' the paper colour, and the tonal and colour scale of a print. A common approach is that followed by Adobe, where a printer profile is used to 'proof' the print on a calibrated screen.

## The Adobe Photoshop software solution - Proof Colors:

The Adobe Photoshop View/Proof Colors command relies on a printer profile to simulate the appearance of a print on a calibrated screen as follows:

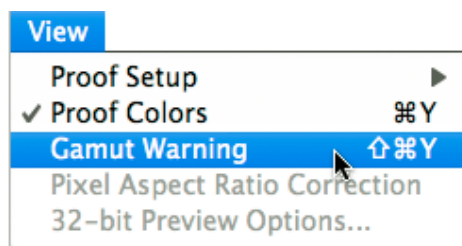


1. Go to Photoshop's View / Proof Setup and select Custom.

2. Choose your printer profile in the Proof Setup dialogue box.

3. Use the Relative Colorimetric Intent with Black Point Compensation to accurately reproduce all colours that are within the printer's gamut.

## Gamut Warning



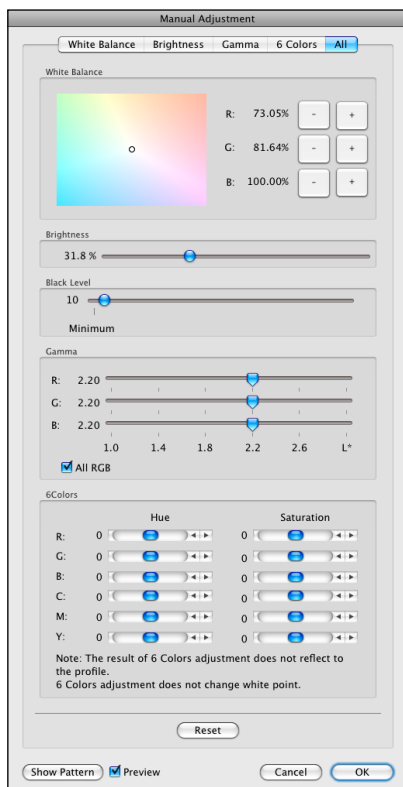
4. Turning on Photoshop's Gamut Warning will reveal any areas of the image whose colours are outside of the gamut of colours that the custom printer profile can accurately reproduce. In some cases these colours are not critical to the overall composition or meaning of the image, on other occasions they are fundamental to its pictorial success, and as such need to be carefully brought 'into gamut'. In this case use the Perceptual Intent to harmoniously compress any 'out-of-gamut colours' into the printer's gamut.

Adobe's 'Proof Colors' solution assumes accurate custom monitor and printer profiles. Generic profiles will produce misleading results. But being entirely reliant on the printer profile's B2A tables for the soft-proof simulation ignores other essential factors including the monitor and how its screen is calibrated, what light source the print is being viewed under, and the observer's adaptation to their environment. Custom monitor and printer profiles on their own will not ensure an accurate match between the print and screen.

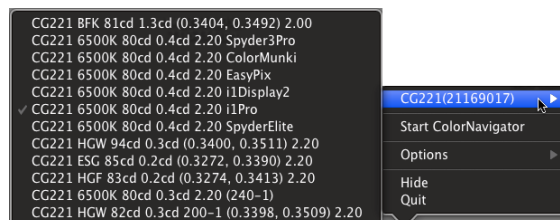
## Hardware solutions:

Many monitors are just not suitable for accurate soft-proofing because they lack the necessary hardware controls for accurate calibration. For example, many screens only allow the luminance of the backlight to be adjusted. Instead the output of their host computer's video card must be compromised to achieve the required colour temperature and tone reproduction curve (typically a gamma curve). This results in a depleted video signal reaching the screen. Such monitors might be perfectly adequate for editing images independent of their printed output, such as web graphics, but are not suitable for soft-proofing. Professional graphics monitors designed for accurate soft-proofing (such as Eizo Color Edge monitors) incorporate high bit depth hardware controls and custom monitor profiling software that provide all the necessary hardware controls for accurate soft-proofing.

The calibration and profiling sequence for professional graphics monitors typically involves creating an initial calibration compliant with the ISO 12646 standard (*See separate notes <http://leswalking.com/texts/monitor.pdf>*). This calibration is used for editing images for web display, or when the image's printed destination is unknown. A series of test images are then printed on the printer and paper of choice and compared under standardised viewing conditions with the screen image. Professional calibration software is then used to visually adapt the monitor's calibration to the printed image. Once a good visual match is achieved the monitor is re calibrated to this new setting which is typically saved under the same name as the printer/paper. This is repeated over time with different images until a good correlation is achieved between what is seen on the screen and what appears in the print. Below (left) is the Eizo ColorNavigator Manual Adjustment dialogue box that provides the level of precise adaptation of the screen to the observer, printer, paper, inkset, and print viewing conditions required for accurate soft-proofing.



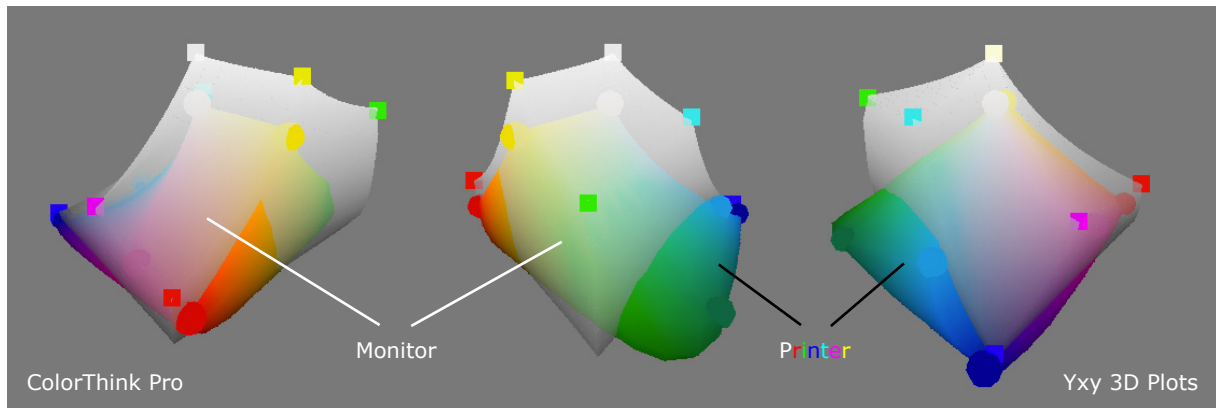
The white balance, brightness and black level (and therefore tonal separation), the tone reproduction curve of each channel, and the hue angle and chromaticity of the RGB and CMY primaries can be customised to match almost any combination of media, observer and viewing conditions. It is then saved as a custom calibrated preset.



The Eizo ColourNavigator Agent (above) allows the immediate selection of different presets (calibrated states) that reference different printing and viewing conditions. Each custom calibrated preset can also be re calibrated over time just as easily and quickly as any other standard.

### Soft-proofing limitations:

Even with a calibrated professional graphics monitor the screen simulation of print colour and tone doesn't always appear as expected. Often the gamut limits of the printer are not entirely contained within the gamut boundary of the monitor. A 3D plot of the gamut volumes of a typical professional monitor (Eizo) and printer (Epson) clearly reveal these differences in each device's range (gamut) of reproducible colours, as illustrated below:



Any colours in the printer's gamut that are clearly outside of the monitor's gamut can not be accurately represented in a soft-proof. A wide gamut monitor that approximates the Adobe RGB (1998) colour space helps to minimise out-of-gamut errors. However when all important image colours are within both the monitor and printer gamuts, it is much easier to obtain an accurate soft-proof on screen.

It is also not just out-of-gamut colours that can't always be accurately simulated in a soft-proof. Many in-gamut colours are also misleadingly rendered due to the differences between the monitor's light source and RGB filters and the CMYK pigments and dyes in prints. There are also significant differences between how our measuring instruments interpret and evaluate colour compared with our colour vision. Even though the 'colour numbers' may appear to be equivalent, we can nevertheless experience a significant difference between the colour renderings on screen and in print.

The print viewing light can be a source of error due to spectral differences compared to the monitor's light source. In accounting for these differences we can either adapt (modify) the print viewing light to match the monitor, or the monitor's calibration can be adapted to the print viewing light. In almost every situation it is much easier and more accurate to adapt the monitor to the print and its viewing conditions. This also allows a standardised light source to be used for all print viewing, which can also be correlated with the lighting under which the prints will be finally displayed, such as the lighting of a gallery. But this also requires a professional graphics monitor with the necessary hardware controls.

In summary, soft-proofing success is intimately connected with the differences that shape the observer's evaluation of the print and soft-proof, both hardware and software, as well as the observer's adaptation to the soft-proofing environment and their experience, memories, and confidence. These factors are explored in more detail in the following pages.

## Soft-Proofing Theory:

### Monitor and print white point:

Soft-proofing is impossible without a close correlation between the monitor's white point and that of the print. Evaluate this correlation under your working conditions as follows:

- Open a new white filled (255 RGB) document in Photoshop and fit to screen.
- Place a sheet of blank printing paper under the print viewing light.
- Observe any difference between the screen white and paper white points.

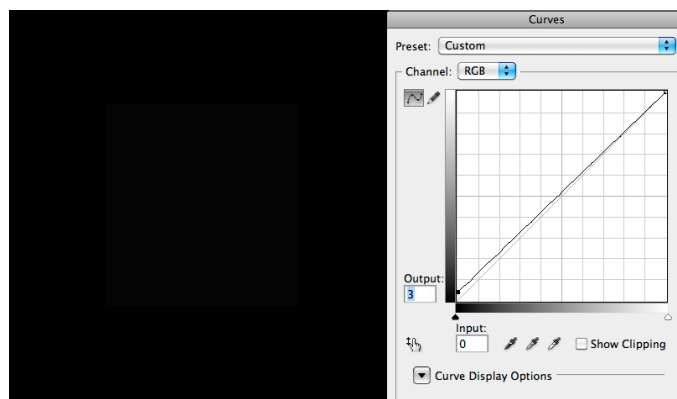
*You will never be able to achieve a close screen to print match (soft-proof) if the screen's white point (luminance and colour) does not match that of the printing paper.*

### Flare level in the viewing system:

Flare is non-image forming light in the viewing system. It degrades shadow separation and black point acuity. Sources of flare include excessively high ambient light levels, dust and smudges on the surface of the screen, and highly reflective screens. Evaluate flare levels under your working conditions as follows:

- Open an new black filled (0 RGB) document in Photoshop and fit to screen.
- Select a sub section of the document and hide the active selection.
- Go to Full Screen Mode (which surrounds the document in black and hides all palettes).
- Open Curves and select the control point (0, 0).
- Drag the curves dialogue off the screen.
- Eliminate all other sources of light in the room.
- Using the keyboard's arrow keys raise the black point one level at a time.

Note the value at which the inner selected black square first becomes visible from the surrounding blackness. On a quality graphics monitor with an accurate calibration this will be around 1 to 3 levels, as illustrated below:



Reestablish your 'normal' room lighting. If this effects the visibility of the inner selected black area, you have flare in your viewing system. The ambient lighting needs to be reduced until there is no visible flare on screen. Light coloured clothing and other environmental factors may also need to be addressed to minimise flare.

### Measuring screen contrast range:

Repeat the previous (flare) test only now with a white filled document and screen. Lowering the 255RGB curve control point of the selected area should show a just visible difference between 255 RGB and 254 GRB, and an obvious difference between 255 RGB and 253 RGB. If this is not the case, carefully check your monitor's hardware settings and software calibration before re profiling and repeating this test.

Once the black and white luminance of the calibrated monitor has been verified, measure in a minimal flare environment the screen's Dmax and Dmin by measuring black (0RGB) and white (255RGB) patches on screen with a spectrophotometer such as Xrite's i1Pro. Alternatively some monitor profiling applications include a calibration report showing the screen's white and black luminance in cd/m<sup>2</sup>.

The ratio of black point to white point is the contrast ratio of the screen. For example:

$$\text{White Point } 100.0 \text{ cd/m}^2 \div \text{Black Point } 0.5 \text{ cd/m}^2 = 200:1 \text{ Contrast Ratio}$$

Note: If your printing workflow includes Photoshop's View/Proof Colors soft-proofing command with a relevant printer profile, you should use the measured screen densities (for the 0 RGB and 255 RGB patches) to calculate the Proof Colors' contrast range.

### Measuring print contrast range:

Print a small square of maximum black (0 RGB) through your colour managed printing workflow and after a suitable drying time, measure the paper white (Dmin) and black square (Dmax). Divide the Dmax by the Dmin reading to calculate the contrast ratio of your printing system for that printer, paper, inkset, printer linearisation, ink weights and printer profile.

### Correlating screen and print contrast ranges:

If the contrast range of the screen is not equal to the contrast range of the print, accurate soft-proofing will not be possible. An all too common finding is that prints look darker and flatter (showing less contrast) than the screen image. In most cases this is the result of not correlating the contrast range of the screen to that of the print.

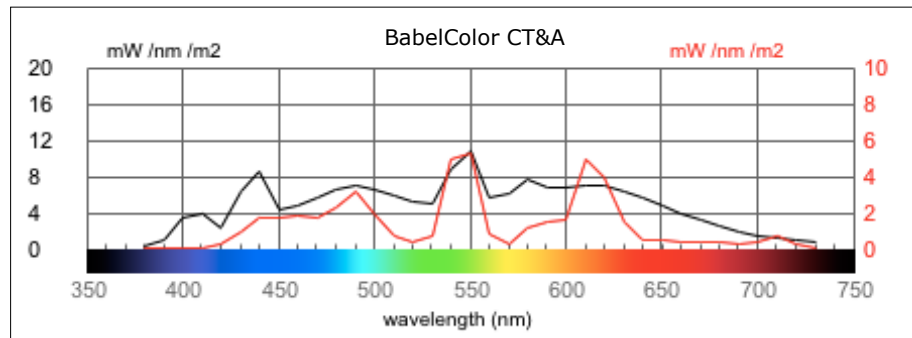
When a wide range of different media are used it may be necessary to have a range of different monitor calibrations (and subsequent monitor profiles) that correlate the screen's contrast range to that of the different media.

Note: Matte surface art papers will for a similar ink weight produce a significantly lighter black (Dmax) than the same ink weight on a glossy paper, because of the higher flare level exhibited by matte surfaces.

### Correlation of monitor and viewing light sources:

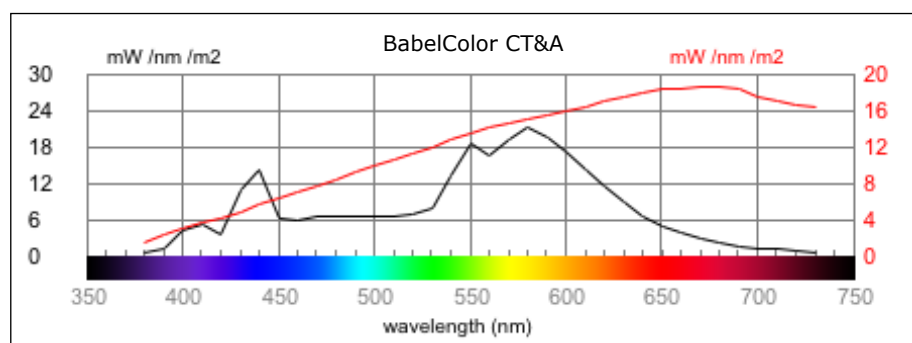
Another typical source of soft-proofing errors is the spectral differences between the monitor's light source and that of the print viewing light. If they are noticeably different it will be very difficult to match the print to the screen.

The following spectral plots illustrate the differences between two fluorescent lights sources:



The **RED** graph is the spectral distribution of a professional graphic monitor's backlight, while the **BLACK** graph is the spectral distribution of an industry standard print viewing lamp. Though both light sources correlate to approximately the same colour temperature, they are not the same. Also both light sources are discontinuous (spiky) and while there is a strong correlation in the greens in the middle of the spectrum (around 550nm) there is significant difference between the blue and red ends of the spectrums. These differences result in the colour appearance differences. For example reds on screen will tend to appear more orange than in print, and the blues will appear darker but less indigo on screen.

The following spectral plots show two different print viewing light sources:

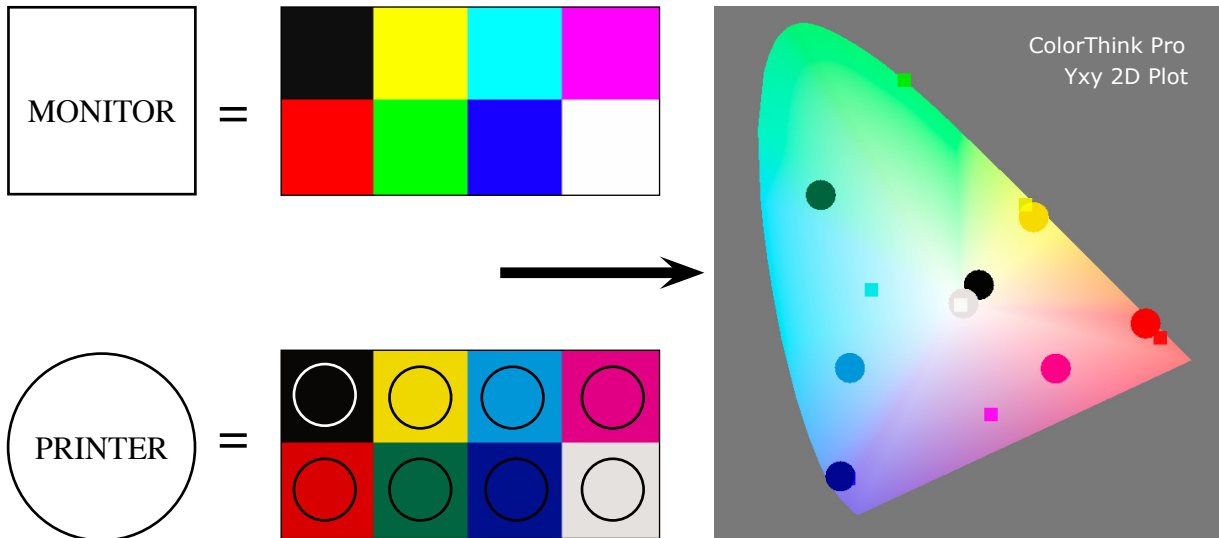


The RED graph is the spectral distribution of a domestic cool white fluorescent lamp, and the BLACK graph is the spectral distribution of a Solux incandescent lamp. Both lamps are rated at 3500°K but the Solux lamp has a measured Color Rendering Index (CRI) of 98 while the domestic fluorescent lamp has a CRI of 62. Prints viewed under these lamps will look very different. A soft-proof will be most accurate under the Solux lamp's continuous spectrum. However the Solux lamp's actual colour temperature of 3490°K will produce a very yellow paper white point that will be difficult to match the screen to. In practice a colour temperature around 5000°K will be easier to correlate white points to.

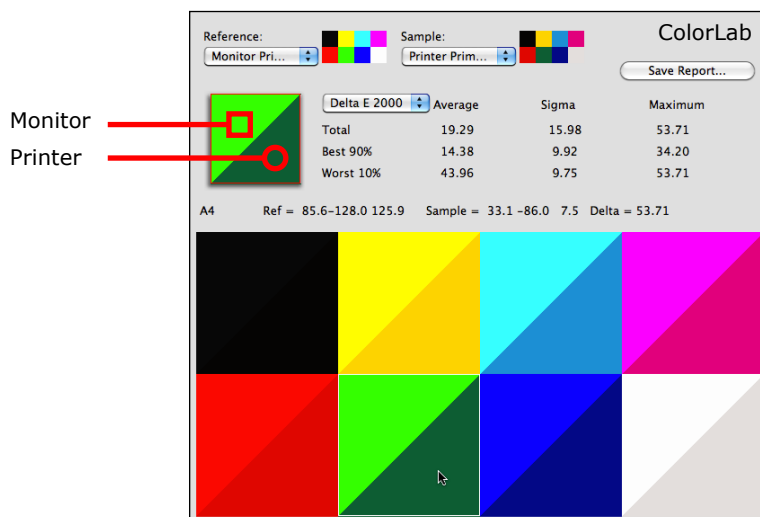
# Soft-Proofing Theory:

## Correlation of monitor and printer RGB primaries:

Colour printers also exhibit device dependent colour gamuts. Therefore comparing the RGB colour gamut of a graphics monitor calibrated to the ISO 3664 standard white point of 5000°K with the CMYK colour gamut of a printer profile that (by default) is also rendered relative to a 5000°K illuminant, produces very different gamut mappings as follows:



In the above Yxy 2D plot the small squares represent the monitor's RGBCMYKW primaries while the larger circles represent the printers RGBCMYKW primaries. The difference between the white points is clearly visible, with the darker printer 'circle' easily differentiated from the brighter and 'whiter' monitor 'square'. The statistical  $\Delta E_{2000}$  (delta E) difference between the monitor and printer plots is also illustrated below:

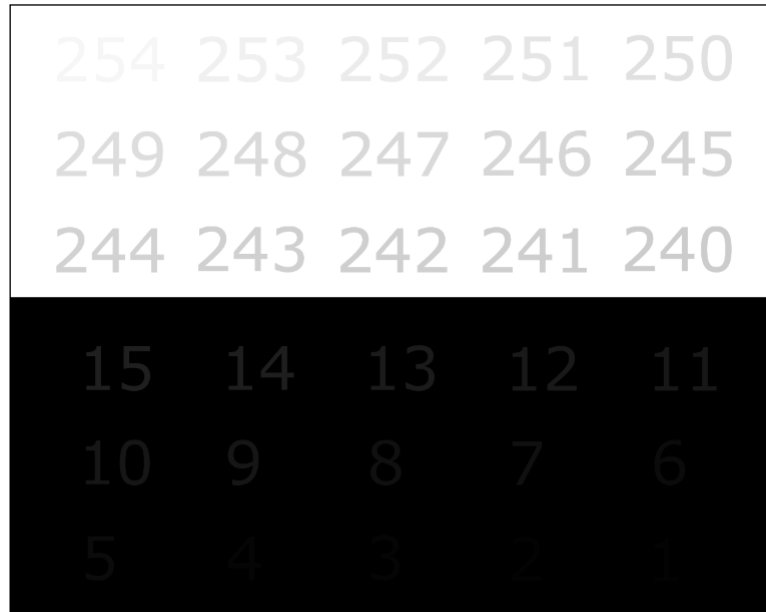


ICC colour management policies are designed to reduce these differences to the point that they are not visually significant. Soft-proofing typically converts the file's RGB values to the printer's CMYK values, which are then converted back to the monitor's RGB values (within the limits of the monitor's gamut) for display as a simulation of the print.

## Soft-Proofing Theory:

### Evaluating printed shadow and highlight detail:

The following printer test form can be used to evaluate under your print viewing conditions the tonal accuracy of your printer profile and soft-proofing workflow. The numbers represent their level of brightness against the white ground (255) and black ground (0). It is printed like any other image and viewed under your normal print viewing conditions.



Typically this test will reveal much darker shadows in the print than can be seen on screen.

This is not just a sign of a poor printer profile, but also a fundamental difference between transmitted light (screen) and reflected light (print). The heavier the ink weight the brighter the viewing light must be for the print's shadow detail to be revealed. The incident light must penetrate the ink, reflect off the surface of the paper, and travel back through the ink layer before becoming visible. While many printer profile default settings will assume a much brighter viewing light (2000+ LUX) than is often encountered, this does not mean that a printer profile can't be created for use under more realistic viewing conditions (400 LUX). But the profile creator must be aware of these difficulties and have the skills necessary to adapt the printer profile to the viewing conditions. Calibrating the monitor at a lower luminance value (80cd/m<sup>2</sup>) will also reduce the visible shadow separation on screen making it an easier match to the print.



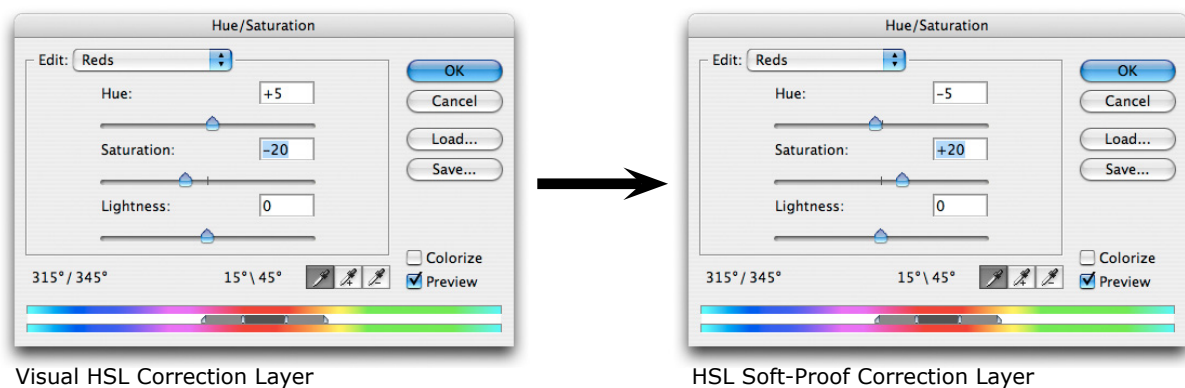
If the values are still not the same, the monitor's Tone Reproduction Curve will need to be adjusted. This is usually accomplished by calibrating the screen to a different gamma. Comparing an evenly spaced step wedge print (18 x 15 Levels increments) with its screen image will reveal if the monitor's Tone Reproduction Curve needs to be adjusted. As the monitor's gamma approaches 1.0 the shadows become progressively lighter.

### HSL Soft-Proof Correction layer:

The most accurate soft-proofing solution is based on a hardware calibrated professional graphics monitor. But if such a monitor is not available but there are obvious colour differences between Photoshop's Proof Colors simulation and the printed image, a HSL Adjustment Layer can be added to visually correct the screen rendering to that of the print. The following work-around can be substituted for a lack of suitable hardware controls on the viewing monitor.

A HSL Adjustment Layer is used to represent the differences between the screen image and its print and thereby quantify what has been modified by the printing and viewing conditions. For example, the print may be darker or lighter or more or less saturated than the screen image. The HSL Adjustment Layer can be used to record these differences by adjusting the HSL values until the soft-proof on screen matches the printed image.

The 'HSL Soft-Proof Correction' layer is then created by inverting the HSL adjustments before saving it. In other words, plus (+) all the minuses (-) and minus (-) all the pluses (+) in the original HSL Adjustment Layer as illustrated below.



Individual 'HSL Soft-Proof Correction' layers can be created for different printer/paper/ink combinations and viewing conditions. Apply the 'HSL Soft-Proof Correction' layer when proofing in Photoshop. Note that this is being applied in addition to the printer profile in the Photoshop's Proof Colors dialogue box. In the above example, in order to match the soft-proof to its print, the HSL Adjustment Layer decreased the red saturation by -20%. The 'HSL Soft-Proof Correction' therefore reverses this finding to +20% red saturation which will automatically add to the image file the 20% red the printing process removes. The print will now more closely match the soft-proofed screen rendering.

### Soft-Proofing with a RIP:

If the RIP includes a custom linearisation for each printer/paper/ink weight, this adjustment will be 'absent' from the resulting printer profile. Therefore the Photoshop proof will be inaccurate and misleading. In this case, it is preferable to soft-proof through the RIP (if it has that facility) where the linearisation curve *and* printer profile are correctly applied to the soft-proof just as they are in the print path.