Fogra
Softproof
Handbook

Fogra Softproof Handbook Version 1
Tips and background information
for colour reliable work on screen

This handbook is the result of current investigations from the Fogra research project, "Creation and investigation of a softproof workstation". It reflects the most recent experiences and test results. Due to new software versions and relevant findings, it has been planned to produce an updated version of this handbook in the near future. In the meantime, updated content can be found on the website at: research.fogra.org. This website has information on current projects, and in the download centre, programs and further instructions on softproofing.

The publication of this handbook, especially in parts requires prior consent by Fogra. In general we welcome the circulation of the complete handbook.

We would like to especially thank the project acompanying committee for assisting us in this research project:

Contents

"It works,
if you know what to do!"

Take Home Message
Target Settings for Calibration*

RGB		CMYK	
Gamma:	According to the Working Space	Gamma:	L*
Colour Temperature:	5000 - 6000 K	Colour Temperature:	5000 - 6000 K
Luminance:	160 cd/m²	Luminance:	160 cd/m²

+ visual adjustment towards the print
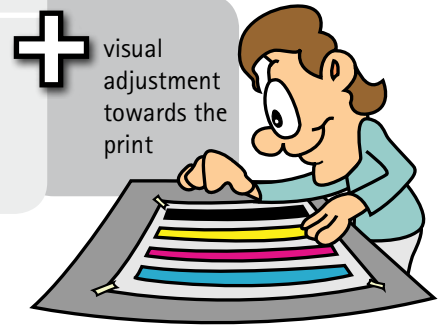
Default Settings in Photoshop*

Color Settings

Unsynchronized: Your Creative Suite applications are not synchronized for consistent color.

Settings: Custom

Working Spaces
RGB: eciRGB v2
CMYK: ISO Coated v2 (ECI)
Gray: Black Ink – ISO Coated v2 (ECI)
Spot: Black Ink – ISO Coated v2 (ECI)

Color Management Policies
RGB: Preserve Embedded Profiles
CMYK: Preserve Embedded Profiles
Gray: Preserve Embedded Profiles
Profile Mismatches: ☑ Ask When Opening ☑ Ask When Pasting
Missing Profiles: ☑ Ask When Opening

Conversion Options
Engine: Adobe (ACE)
Intent: Absolute Colorimetric
☐ Use Black Point Compensation
☐ Use Dither (8-bit/channel images)

Advanced Controls
☐ Desaturate Monitor Colors By: 20 %
☐ Blend RGB Colors Using Gamma: 1.00

OK
Cancel
Load...
Save...
Fewer Options
☑ Preview

Hint!

Absolute colorimetric provides the correct CIELAB data with the Info palette. Please use "Convert to Profile" for image separation, because changing the image mode (e.g. Image > Mode) does not give you a preview and control of the conversion options.

Print Preview*

Example for RGB Printing

Customize Proof Condition

Custom Proof Condition: Custom

Proof Conditions
Device to Simulate: eciRGB v2
☐ Preserve RGB Numbers
Rendering Intent: Perceptual
☐ Black Point Compensation

Display Options (On-Screen)
☐ Simulate Paper Color
☐ Simulate Black Ink

OK
Cancel
Load...
Save...
☑ Preview

Example for Conventional Printing

Customize Proof Condition

Custom Proof Condition: Custom

Proof Conditions
Device to Simulate: ISO Coated v2 (ECI)
☐ Preserve Numbers
Rendering Intent: Perceptual
☐ Black Point Compensation

Display Options (On-Screen)
☑ Simulate Paper Color
☑ Simulate Black Ink

OK
Cancel
Load...
Save...
☑ Preview

* The indicated values are practical recommendations. They can be used as a working example in many cases. However, they do not represent the best values for all situations, and therefore, are not to be regarded as a the "Fogra recommendation". This guide provides extensive background knowledge and many tips for the optimal values to use.

1. Parameters for Softproofing
1.1 What is a Softproof? – Practical Scenarios

Today, even complex jobs are constantly being produced at a quicker rate in the printing industry. Due to time and cost, high-quality printed product is more and more required. Therefore, even as early as the creative agency or data entry, preparation with respect to the colour results is to be carefully judged. For digital proofs, the Ugra/Fogra Media Wedge CMYK V.2/V.3 serves, nationally and increasingly internationally, as a control strip. With this control strip, it can be guaranteed that the proof is colour reliable for the embedded printing condition, such as FOGRA39. Additional information is found in Fogra extra No. 16 „How about the colour reference in digital printing" (http://fogra.org/products-en/download/Extra-16web.pdf). If there is no control wedge on the proof or the tolerances are exceeded, a colorful print is considered to be non-binding. This digital proof enables advantages over the classic on-press proof, in terms of time, quality, and cost. Proofers, proofing material, colour measuring instruments, and software are required for such a system; moreover, it is important to calibrate regularly.

In the daily comparison of proof and print, it is assumed that the print will be subjected to production tolerances. Even so, it is required that the technology related to the simulation is at least equal to the process it is simulating, in particular, compared to the colour gamut to be simulated. With softproofing, this expense could be diminished, which could provide further cost and time advantages. Softproofing can be more concretely defined as the following:

"Representation of an image produced using a monitor with the purpose of showing the results of the preparation (colour separation) process in such a way that closely simulates the results of the intended output (printing) condition." (ISO 12646)

The question remains about the meaning of "close".

Colour-Matching Practice – Three Scenarios

The practice of colour-matching in the graphic arts industry is very multi-faceted, but should be represented here in three typical scenarios. These differ essentially through the object being examined and/or the respective viewing conditions.

Scenario I
Colour-Adjustment on Screen – "Photographer's Workflow"

The colour-matching at the beginning of the production process is not yet defined by a particular standard. The colour-matching object in this scenario is a digital image; regardless of whether it came from a digital camera or was developed on screen, the task is to guarantee a colour accurate screen representation of this digital file on a screen that has been correctly adjusted and calibrated on a regular basis.

Figure 1: Typical viewing scenario in "Photographer's Workflow"

Scenario II
Comparison of Screen and Viewing Booth – "Conventional Reproduction Workflow"

Typical objects of the second scenario, such as textiles, prints, photos, and proofs are supposed to be adjusted on screen and/or serve as a reference for the reproduction. Most frequently, it is used to create a simulation of the original print according process standard offset printing (PSO). Typically, the screen and viewing booth are located directly next to each other, see Figure 2.

Figure 2: Typical viewing scenario in "Conventional Reproduction Workflow"

This is the "Conventional Reproduction Workflow" where the screen and viewing booth are mutually adjusted. The viewing booth is dimmed and the monitor calibration can be visually finetuned. In a closed-loop system, this scenario works quite well, because each part can be adjusted based on each other. Even a lamp replacement of the viewing booth will not be critical, because the monitor can be adjusted/finetuned accordingly. In this second scenario, the highest quality standards for the agreement between monitor and print are demanded.

Scenario III
Colour-Judging at the Final Stage – "Printer's Workflow"

The third scenario is relatively new in the printing industry and, therefore, not much scientific research has been performed yet. The object of the colour-matching is the finished printing product.

As opposed to the conventional process, this standardized procedure (PSO), in which a contract proof represents the reference at the press console, the monitor representation serves as a colour reference. Such systems are also used for image inspection. A typical construction is shown in Figures 3 and 4.

The screen is fixed to a mobile arm and illuminated by the background illumination as well as the viewing booth.

Figure 3: Example of a pressroom console with an integrated screen

Figure 4: Example of a pressroom console with an integrated screen

Hint!

Process Standard Offset Printing (PSO) = ISO 12647-2 + „practical guidelines" + „explanations"

1.2 Fundamentals of Softproofing

Difference between colour conversion of data to the target colour space and colour conversion for display

It is important to understand the colour conversion chain in softproofing which is explained in the following. All digital files have a starting point, for example, from databases, digital photography, or creation on screen. They normally use a device dependent colour space. This usually includes the use of greyscale (K), RGB, and CMYK colour values (e.g. driving values). To understand colour conversion, it is very important to differentiate between the colour conversion of the file (e.g. separation from an RGB working colour space to a CMYK colour space for output) and displaying this "separated" file on screen. The first step is usually done by means of one of two different rendering intents, either perceptual or relative colorimetric using black point compensation. The so converted (separated) images are then to be converted to the display profile. This twofold conversion is illustrated by the "Proof Setup" dialogue box in Photoshop.

First step: Data colour conversion to target colour space

The settings in the upper black box in Figure 5 pertain to the colour conversion of the data to the target colour space. This will often be an output pro-

file i.e for offset printing. In the example screenshot below, the perceptual transformation is made with respect to the printing condition FOGRA39, (e.g. offset printing in accordance with ISO 12647-2). For this printing condition, we normally recommend data preparation for typical subjects with the industry profile of the ECI: ISOcoated_V2.icc.

Second step: Colour conversion to the display

The resulting CIELAB tristimulus values after the first conversion are then subject for the conversion to the display profile. The CIELAB values are result of an intermediate step and can not be „seen" for them self. In a typical softproof setup one wants to simulate the paper white of a substrate on screen. Therefore the conversion to the display profile will make use of the absolute colorimetric rendering intent. This is achieved by selecting the option "simulate paper color" in the second black box in Figure 5. When no simulation of paper white is needed the the relative colorimetric intent will be choosen for the display on the monitor. Deselect „Simulate Paper Color" in this case. In addition deselecting „Simulate Black Ink" in „Display Options (On-Screen)" will make use of *Black Point Compensation* for the colour conversion to the display.

It should be noted that both the colour conversion of the data to the target colour space and the following colour conversion to the display profile are done on the fly and are not saved to the data. In a later stage although the data normally will be converted to the target colour space which was used in the softproofing setup explained here.

From driving values to colour values

To achieve a colours reliable display on screen the data has to be defined colorimetrically. Similar to the use of a dictionary, through the use of ICC profiles, it is possible to calculate device-independent CIE colour values from device-dependent values such as RGB or CMYK.

Note!

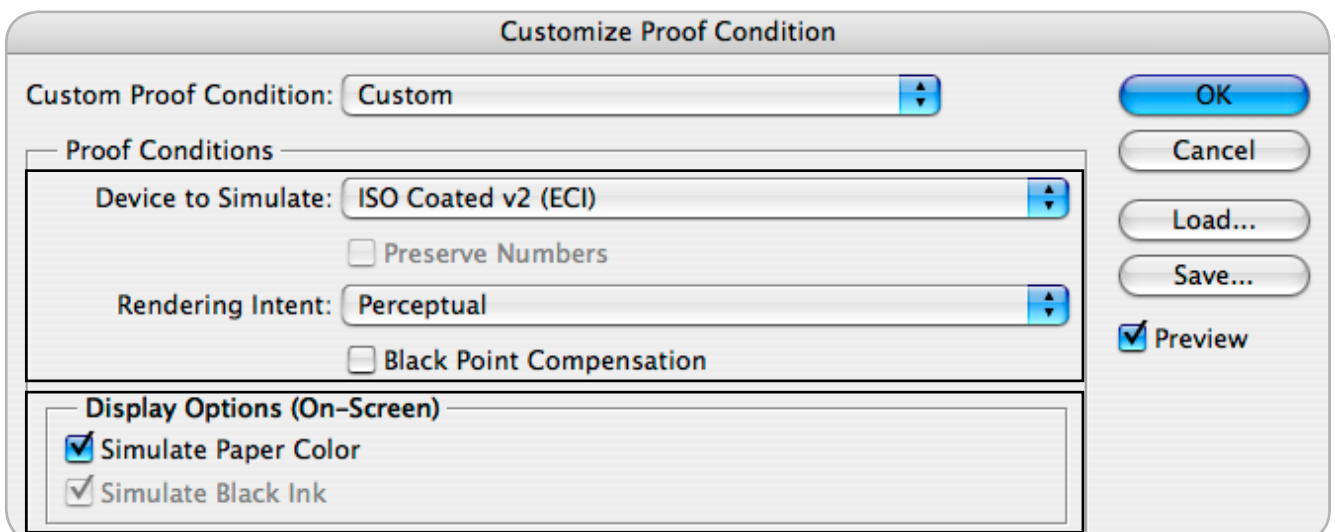In this document, for the sake of simplicity, the driving values will be designated as colour values.

Figure 5: Photoshop Softproofing Dialouge Box: Data separation (upper black box) and transformation to the display (lower black box)

Image Data Representations:
When a file is displayed on a monitor, from a colorimetrical point of view, there are four ways that the colour values can be represented.

1. Monitor representation without colour management
The first way is to send the RGB values of the file without any changes to the monitor. This happens, for example, in programs, such as the Windows Desktop, which is shown in Figure 6 as "direct representation". It is suited for situations in which colour is not binding because based on the different colour behavior of the devices, the same file will always look somewhat different. In the next version of this handbook, we will review which applications support a colour managed monitor.

Ergo:
Preparation: none
Representation: RGB-Data displayed
                          unaltered
                          („keep numbers")

2. "Normal View" in Adobe Photoshop
This representation is used most frequently in the graphic arts industry. Adobe Photoshop is considered the defacto software standard for photographers. With this, the RGB values are converted to the display profile with the relative colorimetric intent with black point compensation. For example, the RGB values 227, 0, 15 in sRGB correspond to the CIELAB colour values 48, 74, 60. In the background, a relative colorimetric conversion to the screen profile occurs. Here, the screen profile

of a MacBook Pro "Color-LCD.icc" with black point compensation delivers the RGB values 250, 0, 0. These values are sent to the graphics card. This leads to an optimum („contrasty") representation in the sense of the utilization of the available screen contrast. For the colour-binding representation of print files, this method is not suitable because the colour values of the file are represented as either very bright and/or dark because the photo contrast is completely scaled to the monitor contrast. Due to this, a representation is displayed that may possibly contain a darker black and lighter white than the original data. However it should be noted that this method achieves a colorimetric match if a hardware calibration set the monitor white and black point to the CIEXYZ of the printing condition to be simulated. Practically this method is sometimes used to get a fairly accurate representation with the „standard" mode (normal view) of image represenation in Adobe Photoshop. This method although limits the versatility of the monitor calibration, because all applications, regardless if colourmanaged or not, will show the „simulated paperwhite. This approach is not recommended in general.

Figure 7: On the left, printed black. On the right, monitor black.

In Figure 7, this effect is shown with the example of black. On the left an absolute colorimetric match of the black patch (CMYK = 0, 0, 0, 100) is shown. On the right is the result of the "normal-view" representation. Due to this, the danger arises that shadow areas in the photos will be incorrectly displayed and judged and therefore modified or left untouched.

Ergo:
Preparation: none
Representation: Relative Colorimetric
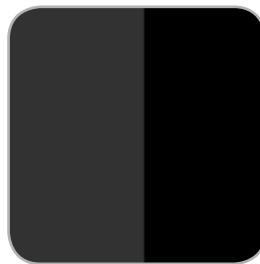   with blackpoint
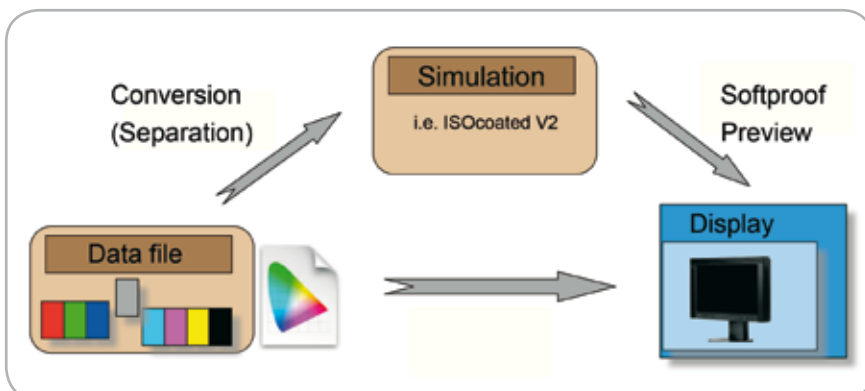   compensation

Figure 6: Principles of colour conversion

3. Colour accurate representation without printing process simulation: "Photographer's Workflow"

For RGB retouching, Photoshop automatically uses the monitor profile for image rendering (using relative colorimetric including black point compensation). Therefore, no further intervention is necessary. The monitor should cover a sufficient colour gamut (wide gamut monitors that can better cover Adobe RGB or ECI-RGB V1/V2). In addition, a print preview can be used as necessary. For example, it can be used for the paper white simulation using a personal inkjet printer (see figure 8). See Figure 9 to determine where to store settings. If you choose a profile before you open your photos, it becomes the default (see Figure 10). The standard printing preview can be activated and deactivated with keyboard shortcuts (Command + Y / Control + Y).

Ergo:
Preparation: Perceptual
Representation: Absolute Colorimetric

4. Absolute Colorimetric Representation With Printing Process Simulation: "Reproduction Workflow"

For the so called "Reproduction Work-flow", the ICC profile of the intended printing condition is used as a simulation profile. For this processing (separation), there are two practically used methods; one is perceptual and the other is relative colorimetric with black point compensation. With respect to the choice of rendering intents, for example, in Photoshop (see Figure 11), it is to be noted that the conversion of CMYK applies virtually in the background.

Ergo:
Preparation: Perceptual
                         (see Figure 11) or
                         relative colorimetric
                         with black point
                         compensation
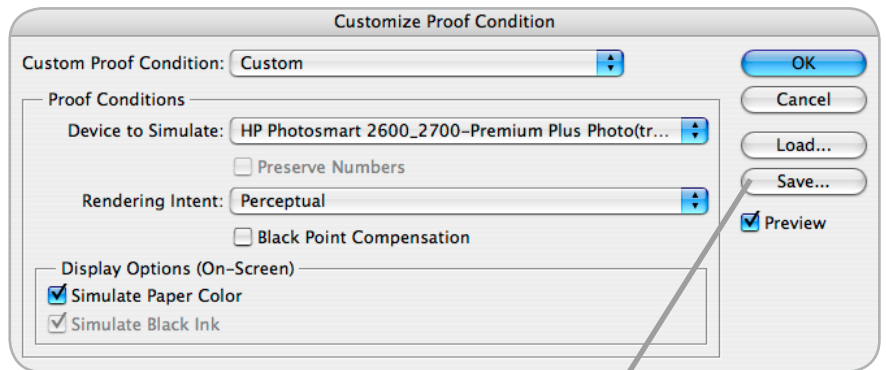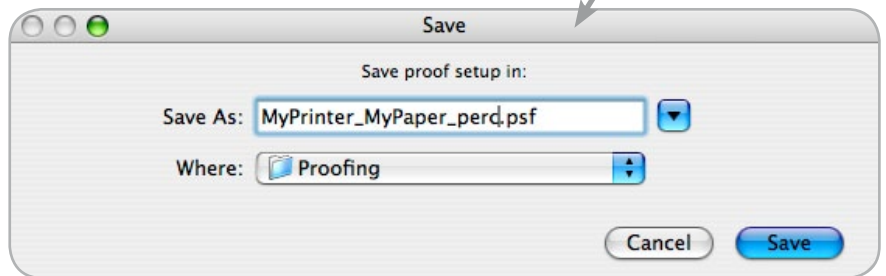Representation: Absolute Colorimetric
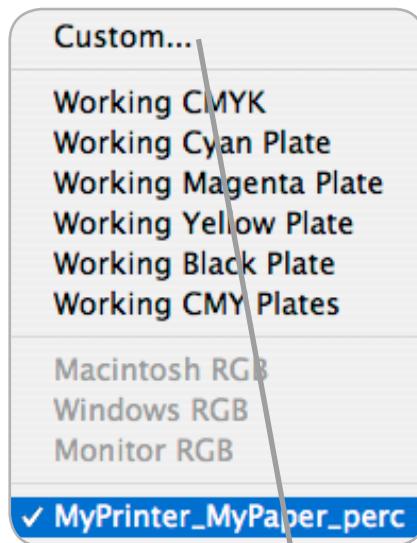

Figure 8: Setting without name

Figure 9: Stored setting

Figure 10: Standard setting
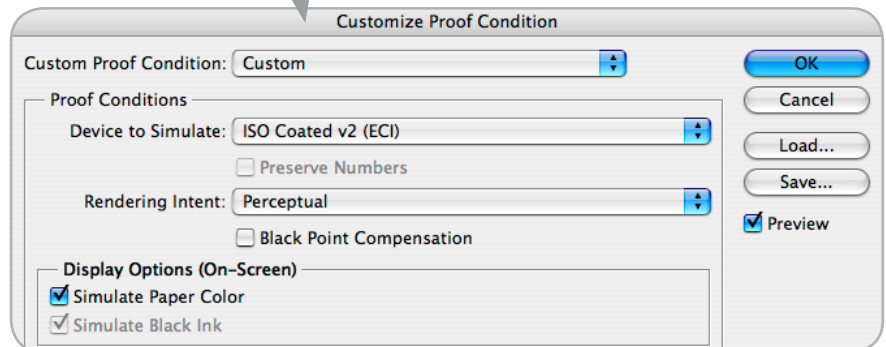
Figure 11: "Proof Set-up" dialogue box in Photoshop

Proofing of CMYK Data

It often occurs that already prepared (separated) files must be reviewed on screen. In this case, the processing and correct representation must be done on screen. In order to simulate the image data as it would be printed without colour conversion, the option to "Preserve CMYK Numbers" in Photoshop must be activated. An example is shown in Figure 12.

Figure 12: Photoshop setting for the proofing of CMYK colour values

1.3 Setting Up a Softproofing Work Station

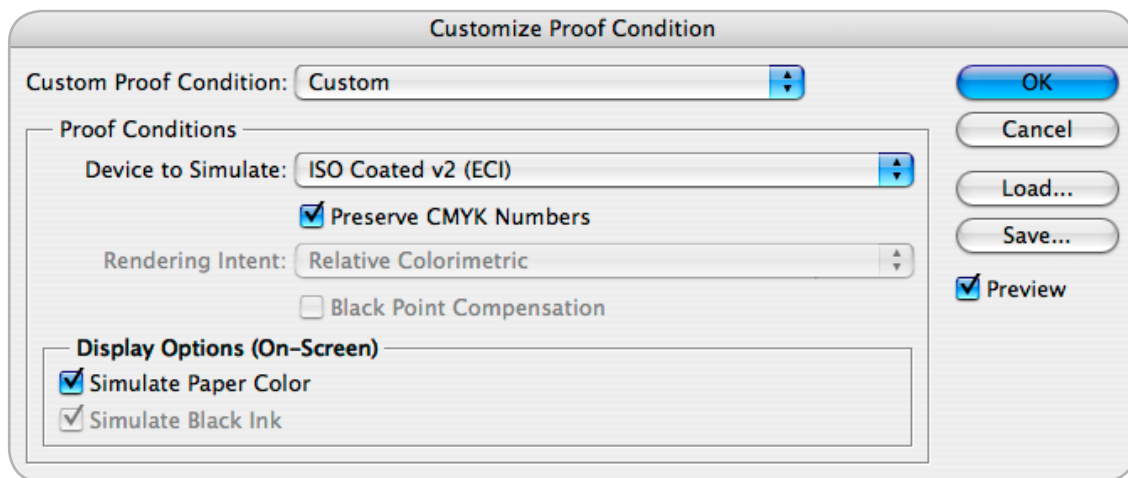The set-up process can be outlined in the three following steps: calibration/adjustment, characterization, and profiling. An additional validation step is considered optional and will be described in Chapter 3.

Calibration/Adjustment

In the first step, the hardware is adjusted by using a colour measuring instrument and further methods (test files, reference prints, visual finetuning etc.) to meet the desired target (aim) values.

Characterization

After the screen has been optimally adjusted, test colours are displayed on the screen and colorimetrically measured. As a result, characterization data has been produced (typically as tabulated data).

Profiling

In the last step, the calculation of the ICC monitor profile is done based on the characterization data (measured before). Furthermore, user dependent options are also considered in the profile creation.

In the following, these three steps are described in greater detail.

Calibration: Hardware or Software?

Calibration

Calibration comprises all adjustments and (active) methods necessary to reach desired aim values such as white point, gradation, and luminance. Hereby, both a smooth rendition of the lightness scale and the utilization of the technical possibilities of the pertinent device must be taken into consideration.

Two Categories of Rendering

The representation of images on the monitor is influenced by many parameters, such as the type of screen, graphics card, DVI cable, operating system and/or driving software. Figure 15 shows typical interfaces.
In Figure 14, a logic classification of the driving is shown. This symbolizes the characteristic flow of the colour transformation from the right to the left. The main components are defined in the following:

ICC profile:

First the image data is passed to the ICC profile. This is done by the program (e.g. Photoshop) used including the utilization of the monitor profile made available by the operating system.

Graphics Card:

Most graphics cards allow the individual modification of the red, green, and blue channels using different bit depths. The concept of how these are used is important for the overall quality of the entire colour management chain.

Screen (display, monitor):

Modern screens offer the possibility for hardware calibration of the display panels both with adjustment possibilities at the user interface ("On Screen Display") or via software activation. Hereby, the amount of the steps is important (e.g. 8, 10 or 12 bits) see Figure 13, since it determines the accuracy of the needed adjustments. It is of great importance to optimize the interplay of hard- and software (communication for example via DDC) in order to achieve the desired target values (white point, gradation, luminance).

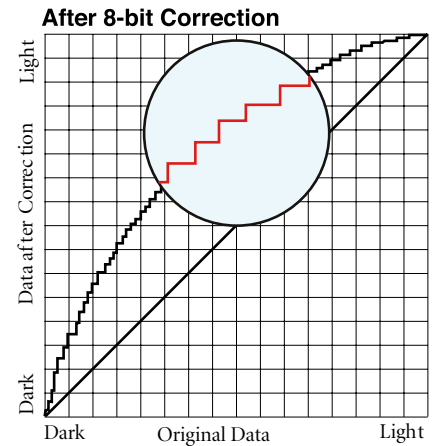**After 8-bit Correction**

After 10-bit Correction

Figure 13: Comparison of 8-bit and 10-bit data representation

A hardware calibration is, therefore, considered to be the preferred case if the necessary corrections (in order to achieve the aim values) can be done where the highest accuracy is available (monitor LUT). Corrections should be carried out with the highest accuracy

Calibration:

Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards [ISO International Vocabulary of Basic and General Terms in Metrology]
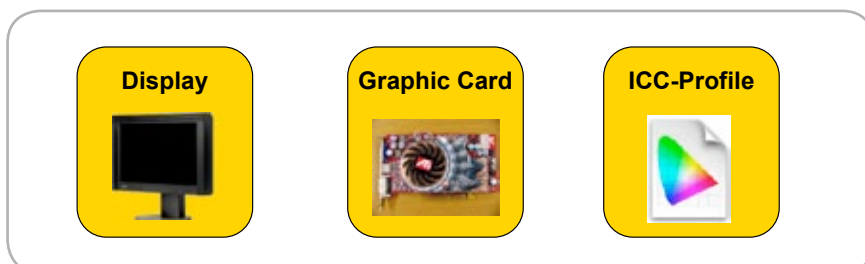

| Display | Graphic Card | ICC-Profile |

Figure 14: Principle representation of the three most important components for the final image quality.

The Shapes and types of video connector

		Connectors on the monitor		
PC	Video Conectors	D-Sub 15	DVI-I	DVI-D
Macintosh	D-Sub 15 pin	❍	❍	✘
	ADC[1]	❍	●[2]	●
	DVI-I	❍	●	●
Windows	D-Sub 15pin	❍	❍	✘
	DVI-I	❍	●	●
	DVI-D	✘	●	●

❍ Analog connection   ● Digital connection   ✘ No connection

⬆D-Sub 15pin

⬆DVI-D 24pin

⬆DVI-I 29pin

⬆ADC

Figure 15: Form and types of different video connectors

possible, particularly in the LUTs of the screen.
In case no hardware calibration is available the necessary corrections must be carried out consequently by using the possibilites provided by the graphics card or by means of the ICC monitor profile. In the optimal case of a hardware calibration the transfer functions of the graphics card and the ICC display profile are linear. Since graphics card normally have a lower bit-depth (often 8-bit) than the monitor LUTs, the software calibration is usually qualitatively not as optimal than the hardware calibration (see Figure 16).

Expert Tip:

There are several DDC versions: In the simple version DDC1, the known data of the monitor is transmitted unidirectionally and permanently as so called EDID data to the graphics card. The information contains records as long as 128 bytes, which standard solutions and DPMS modes support. The screen size and the manufacturer statement are also known. The version DDC2 supports bidirectional communication and enables interaction (e.g. based on colour reading during the calibration, and therefore, hardware calibration, the display behavior can be altered).

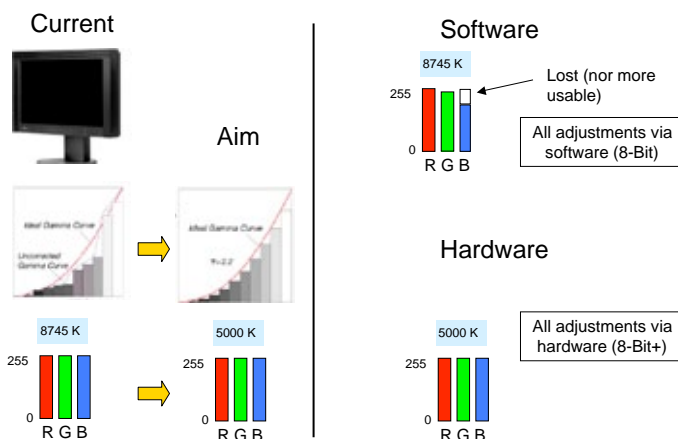Software calibration: On a laptop there is mostly no access to the screen LUTs.

Hardware or Software calibration?

Current

Aim

Software

8745 K

255

0

R G B

Lost (nor more usable)

All adjustments via software (8-Bit)

Hardware

5000 K

255

0

R G B

All adjustments via hardware (8-Bit+)

8745 K

255

0

R G B

5000 K

255

0

R G B

Figure 16: Comparison of hardware and software calibration

Characterization

Characterization links the device depen-dent control (driving) values to their corresponding measured device ind-pendent colour values. This means that for the screen measurement, the RGB values to be sent via the application to the graphics card are compared to the measured CIEXYZ or spectral data (see Figure 17). This is the basis for the crea-tion of the monitor profile. The amount of the test patches to be used depends on the characteristic of the screen. Older cathode ray tubes (CRT) behave roughly in a linear function, in the sense of the additive colour mixture. For this reason, less test colours are necessary for a sufficient colorimetric description in comparison with modern LCD screens. Without correction performed by the manufacturer, many LCDs show worse linearity, so for a sufficient characteri-zation several test colours are necessary.

Profiling

At the last step, with the goal of an optimum colour description (fingerprint) of the screen, an ICC profile is genera-ted based on the characterization data. This means that both the forwards (RGB to CIEXYZ) and the backwards direction

(CIEXYZ to RGB) must contain a high quality transformation. The ability to have both transformation directions at a high accuracy level is of great impor-tance for softproofing. This is shown in Figure 18 by an example. An RGB file with an ECI source profile is supposed to be represented in an absolute man-ner on screen. In the first preparation stage, the data has to be transformed to CIEXYZ. To transform the colour values corresponding RGB values must be found for all colour values that lead exactly to the CIEXYZ colour values calculated before. For that reason, the backward transformation (CIEXYZ to RGB) is necessary. On the other hand, to simulate the representation of an RGB file on different screens, the forward direction is required.

Matrix or LUT?

The ICC profile format specification gives references of how to "store" a colour transformation digitally. Two different methods are used:

- Transformation with tone value reproduction curve (TRC) based on a matrix [MATTRC]
- Multi-stage, Look-Up-Table [LUT]

based on transformation with multi-dimensional tables, matrices and tone value reproduction curves for every input and output channel

As a rule of thumb, the user should follow the recommendations of the manufacturer of the calibration system. In case no recommendations are given, both a LUT and a matrix profile should be created and evaluated visually. Generally, LUT profiles can better mimic non-linear system behavior. A technical validation is a valuable recommendation and should be performed in addition to the final visual evaluation of the display calibration. The validation should be repeated in regular intervals in order to be able to recognize a variation of the softproofing system.

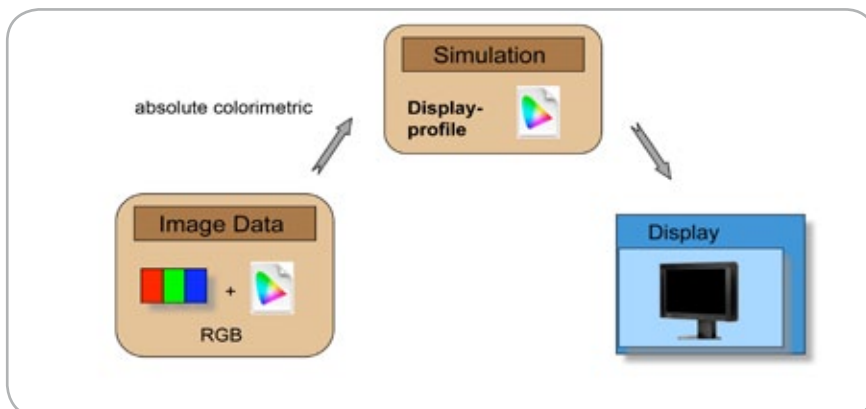Figure 17: RGB characterization data generated by ProfileMaker

Figure 18: Photoshop setting for proofing of CMYK colour data

1.4 MAC or Windows: What is there to consider?

Today, in digital image preparation the choosen operating system generally doesn't play an important role. Files can be exchanged primarily without problem between the "Windows World" and the "Mac World". Nevertheless, for softproofing needs, there are some platform dependent details to consider. The following has references to up-to-date available operating systems of Apple [Mac OS X from 10.3] and Microsoft [Win2000, WIN2003, Win XP], see Figures 19 and 20. Older operating systems are not discussed here.

Colour Management in Windows Vista
At this point, no recommendations can be provided due to lack of investigations.

Where do I deposit ICC profiles?

Mac OS X
Under Mac OS X, there are four places where the system stores ICC profiles. This often enables a user to have specific storage of ICC profiles (e.g. industry standard RGB and CMYK profiles), see Figures 21 and 22. The monitor calibration software usually puts the ICC profiles automatically into one of these folders. Some solutions permit the choice of folder location. Yet, in addition, profiles are found in the System folder and in the Library Application Support folder.

Windows
In Windows, the profiles are located under the following path: C: \windows\ system32\ spool\drivers\color. The monitor profile can be set in the display options of the operating system (see Figure 19).

The monitor calibration software auto-

matically deposits the ICC profiles in this folder. If one would like an additional profile, for example ECI RGB or ISOCoated_V2, it can be installed using a right mouse click on the filename and selecting „install profile". Through this, the profiles are copied automatically into the correct folder, and also, the profiles are made "known" to the system.

Special Options in Mac OS X
For calibration and profiling under Mac OS X, it must be noted that in the System Preferences (see Figure 23) the contrast setting is set to "normal". It is recommended that the user deactivates the relevant keyboard shortcuts, since the contrast setting can be easily changed by mistake otherwise.
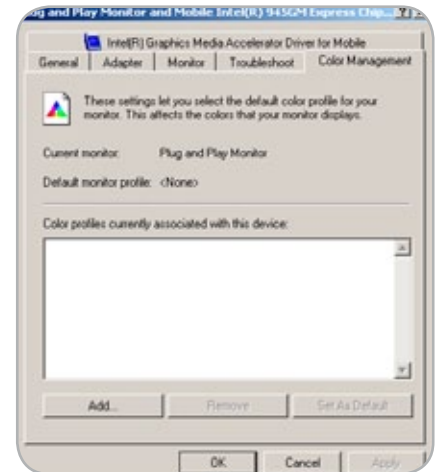

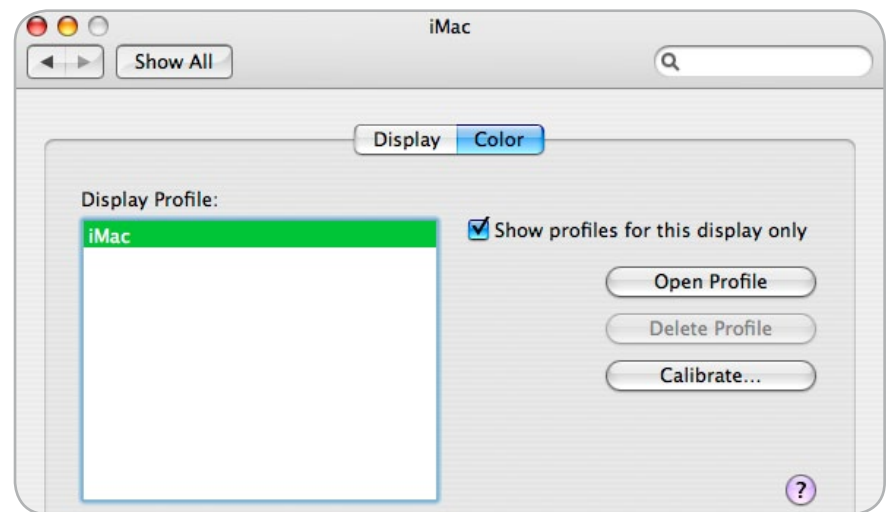Figure 19: Selection of monitor profile in Windows XP

Figure 20: Selection of the monitor (display) profile under Mac OSX
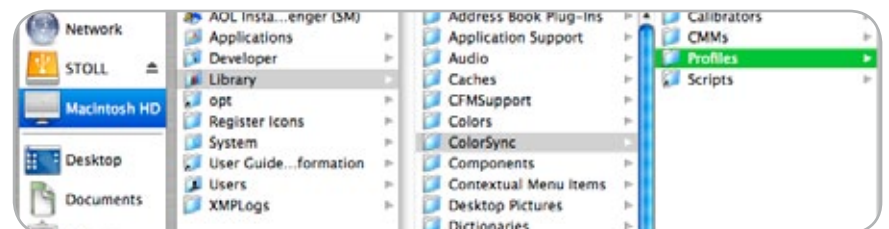

Figure 21: Under "my hard drive" (/Library/ColorSync/Profiles) profiles that are available to every user of the computer can be found.
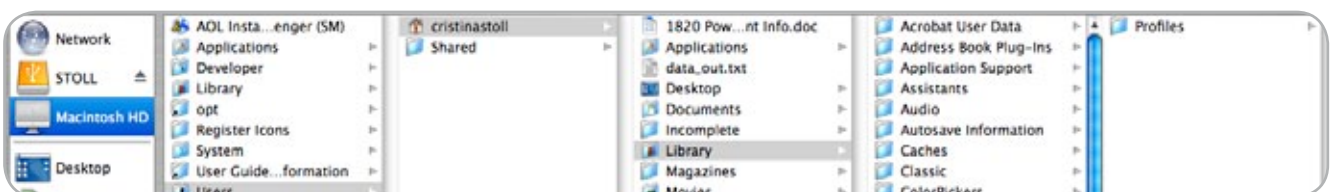

Figure 22: User specific profiles are found under "my hard disk" (/User/My User Name/Library/ColorSync/Profiles)

Using More Than One Display

It is common in the graphic arts to work on more than one screen (see Figure 24). The second monitor is often designated as a palette monitor where the toolbars are desposited, and therefore, the total area of the main monitor is available as a work area. But the second display might also be a Plasma TV that should match the primary display. For a correct representation, both screens should be calibrated.

Windows XP permits only one ICC profile per graphics card. There is, however, three possibilities for several monitors to operate and the ICC profiles to be set correctly.

1. Two Graphics Cards – Connection of the Second Monitor at Second Graphics Card

If the cards are the same or come from the same chip manufacturer, this will be much more simple. Under Windows Vista, the graphics card chips must be from the same manufacturer because generally Vista cannot simultaneously work with different graphics card drivers.

2. Dual–head graphics card simulating to the OS to behave like two separate graphics cards

With this, an ICC profile is allowed for every output connector. This seems to be the best possibility, as it offers more screens for use. There are relatively low-priced and simple graphics cards (e.g. by Matrox) that offer this possibility.

3. Microsoft Color Control Panel Applet for Windows XP

This is available free of charge under http: //www.Microsoft. com/downloads/details. Aspx?FamilyId=1E33DCA0-7721-43CA- 9174-7F8D429FBB9E&displaylang=en. The Color Control Applet is shown in the system control and allows to assign ICC profiles to certain devices, also several monitors. Aside from this, it permits a simple administration of the ICC profiles and has a gamut viewer. For multi-monitor use, one should read the documentation of the program and should proceed accordingly. The disadvantage of this solution is that in the OS colour settings, only one profile is shown. Though it is not easy to check
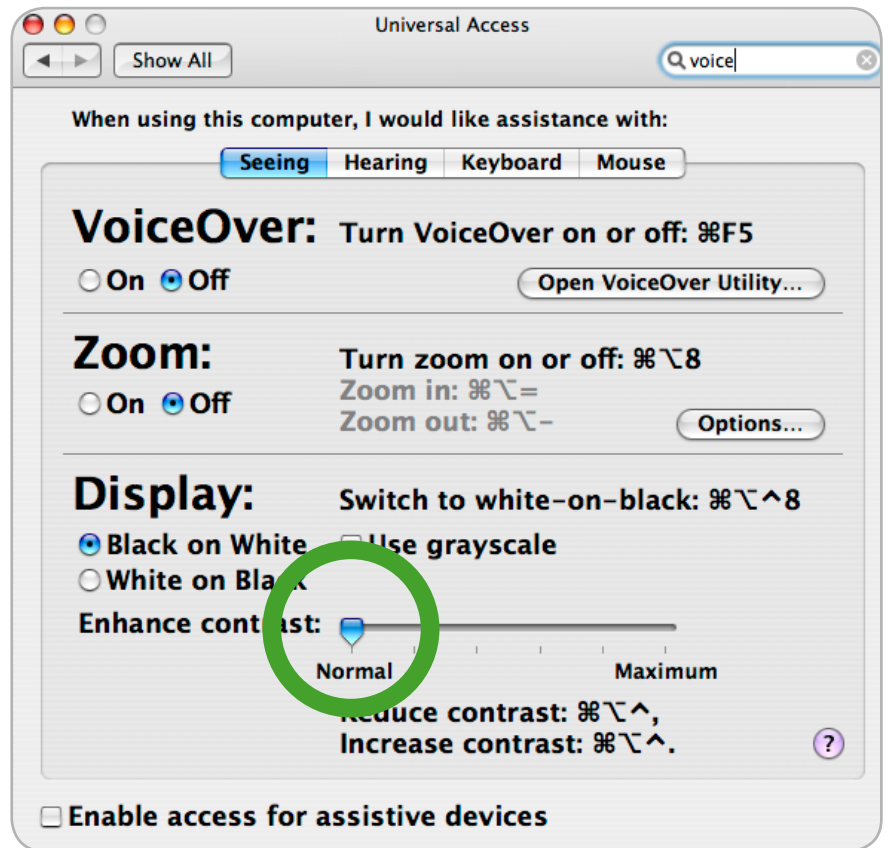
Figure 23: Screenshot of the optimal operational settings

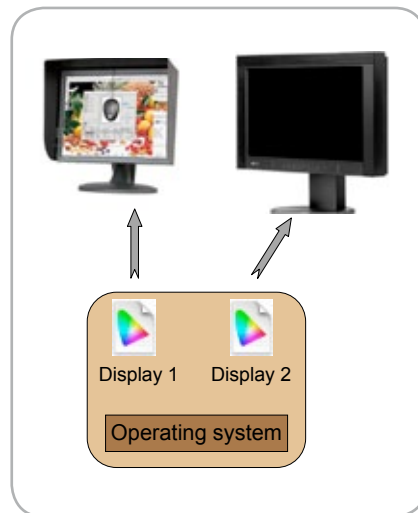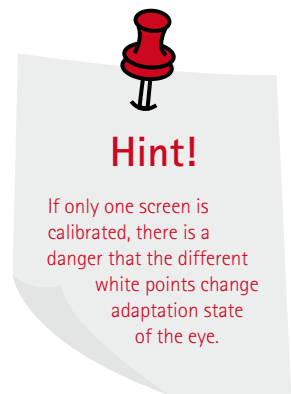Figure 24: Example of double screen setup

if and for which monitor a profile is active; in this case, so-called test profiles can be used to gather that information. This is a simple no-cost solution, but error prone and therefore only recommended for experienced users.

Hint!

If only one screen is calibrated, there is a danger that the different white points change adaptation state of the eye.

16

1.5 Measurement Devices for Softproofing

For high-quality softproofing, the use of a colour measurement devices is necessary. It has been proven that the human eye has an excellent gift for seeing colour difference, however, it is very bad in the absolute estimation of the colour (based on colour memory). In this section, after a short survey on the subject of colour measurement, the use of practical colour measuring instruments is introduced.

Brief Introduction to the Colour Measurement of Self-Luminous Objects
The colour measurement of self-luminous objects, like a monitor, is done without a white standard, which is necessary for the reflection measurement as a reference, see Figure 25. Basically, the emitted light is weighted by the Colour Matching Functions (CMF) of the eye (e.g. 1931, 2 degree, normal observer) followed by a suitable normalization (e.g. Y = 1 for the white point).

Colorimeter and Spectrophotometer
For colour measurement, there are basically two different methods: the colorimeter and the spectrophotometer. Colorimeters have built-in filters, aiming for an optimal fit against the CMF (see Figure 26). Therefore, they are designated as filter measuring instruments. The accuracy of the filter adaptation to the CMF indicates quality of the instrument. A typical colorimeter is shown in Figure 29.

To determine the CIEXYZ colour values, the transmitted light is separated directly into single spectral areas and applied with further correction procedures, such as 3 by 3 matrices. The latter are dependent on the screen, and according to the monitor type (and backlight) used, different corrections might be necessary.

Based on the different spectral characteristics of modern screens with larger colour gamuts, a different correction is necessary for different LCD screens. The resulting CIEXYZ colour values can be roughly interpreted as follows:
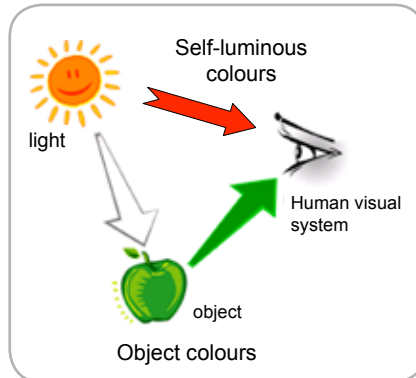

Figure 25: Colour measurement: Self-luminous and object colours.
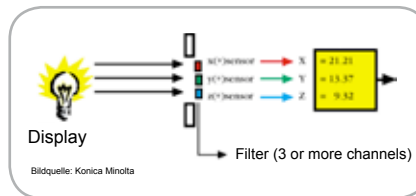

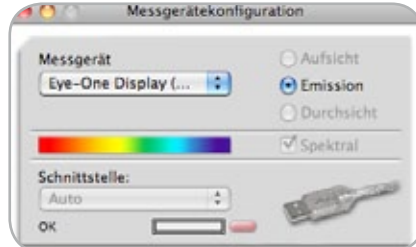Figure 26: Schematic representation of the functional principle of a colorimeter.

Figure 27: Measuring instrument configuration with ProfileMaker.

- the X component corresponds with the red channel
- the Y component corresponds with the green channel and simultaneously, the luminance
- the Z component corresponds with the blue channel

Spectrophotometers function under another principle. The transmitted light is dispersed by means of a prism or a diffraction grating into its spectral parts. The weighing with the CMF is often done by means of a software program in the measuring instrument. A spectrophotometer is shown in Figure 28.

Hint!

A definition and the explanation of the difference between spectral radiometer, and spectral photometer can be found on page 37.

Hint!

For information on emitted light and emissive measurement, see Figure 27.

Expert Tip:

Compliance of the Luther Condition

Expert Tip:

The spectral characteristics include the interaction of narrow-band emission of the background illumination (CCFL or LED), the spectral transmission characteristics of the colour filter within the LCD panels and the respective filter curve sensitivities of the measuring instrument.

Expert Note:

In order to maximize saturation the spectral radiances become spectrally more and more narrow and „peaky". Strong problems arise, when the peaks overlap the steep parts of the CMFs. This strongly challanges the correct measurement of flat panel displays.

Problems arise if no energy is emitted in those „gaps" where the CMF have sequential overlaps. A slight change in the emitted light might cause a dramatically different colour appearance.

Please note that the distinction between hand measuring instruments and/or laboratory measuring instruments is not made here. Essentially, the laboratory measuring instruments are indicated by improved optics, better temperature stability, and higher quality of filters and/or spectral resolution (sampling).

How do spectrophotometer and spectroradiometer differ?

In this section, the difference between a spectroradiometer and a spectrophotometer will be explained. The difference between both device types is that they measure different quantities. A spectroradiometer measures radiometric (energetic) quantities. For example, like power per wave length (watt/nm) on a receiver. Consequently, a costly calibration is necessary.

Spectrophotometers are substaintially more simply constructed. They measure relative quantities (ratios), such as the reflection factor. For this, they require one (white) reference with a given reflection factor. This reference can be the paper substrate (as for relative density measurements) or the perfect diffuser for colorimetric measurements. For example, the i1 Pro is a spectroradiometer because it measures the radiance emitted by the display. For ambient illumination measurement, this absolute calibration is also required. The SpectroEye or SpectroDens are typical spectrophotometers because they always require a reference. In colorimetry, the refrerence white is the built-in white tile, and in densitometry, the paper or the reference white (relative vs. absolute densities).

Operation in Practice

The use of the colour measuring instruments is relatively easy. Most devices have a USB connection, so that after a driver installation, the device is operational. At the beginning of every measurement, according to device type, a black calibration may be necessary. For this, the instrument is placed on an opaque area, so that no light will reach the sensor. The calibration software normally will give guidance how to do the black calibration for a specific device.

Figure 28: Image of a spectrophotometer

Figure 29: Image of typical colorimeter

	Colorimeter	Spectrophotometer
Advantages	compact	spectral information
	low-priced	no correction of different display types necessary
	good signals to noise ratio	maintenance through the manufacturer
Disadvantages	no spectral information	Measurement of dark colours might be problematic

Table 1: Basic advantages and disadvantages in the comparison of colorimeter and spectrophotometer

1.6 Displays (Monitors)

The term "monitor" can be summarized as a device that transfers an electric signal into an self luminous colour image. Monitors exist in the middle or first stage of each softproof job, and are used to display colours through additive colour mixture (primaries of red, green and blue). Based on the decline of CRTs in daily practice, they are not reviewed in this handbook in detail. Rather the focus of this handbook lies on LCD screens, whereby only the relevant portion of the technology is overviewed.

LCD screens using liquid crystals fluids, which possess, at a certain temperature, characteristics that are only otherwise found in crystals. Thus, they can show double refraction (e.g. different index of refraction for different levels of polarization). Those optical characteristics can be controlled by electrical or magnetic fields.

If a thin layer (a few micro meter) of liquid crystal is put between two glasses, on which transparent electrodes are mounted, the transmittance can be altered through variation of a controlled electric voltage. In addition, crossed polarizers must be mounted as shown in Figure 30. Transparent thin film transistors (TFT) utilize the voltage for each pixel, and therefore regulate a screen is often called a TFT screen.

By these filtering functionality the permanent background illumination is darkened more or less on a pixel by pixel basis. If one applies colour filters now on the surfaces of the individual pixels, then a colour monitor is established governed by the laws of additive colour mixing.

LCD vs. CRT in a nutshell
Modern LCD monitors show an advantage in respect to their colour rendering,

temporal and local homogeneities, improved picture distortion, as well as the maximal luminance in comparison to the CRT monitors. Further characteristics, such as being flicker-free, being immune to electromagnetic fields, and the slight weight, make it increasingly more popular for the prepress work.
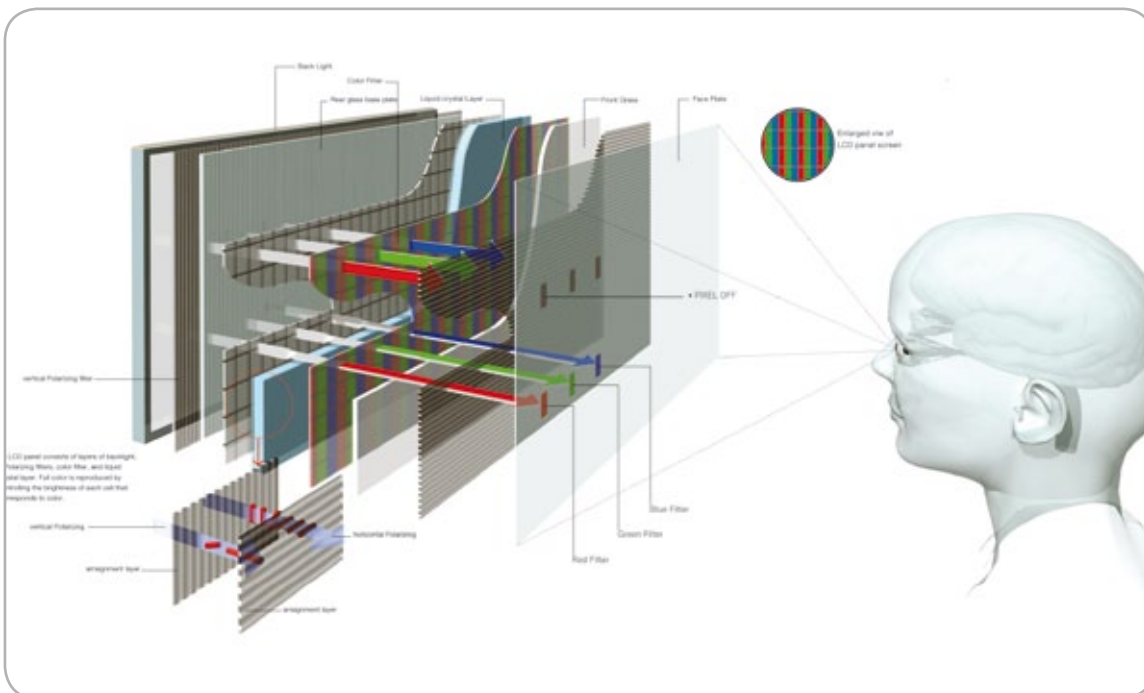

Figure 30: Basic construction of an LCD screen. Source: EIZO

Format and Homogeneity

A basic criterion for softproofing displays is the display format. While large-format inkjet printers already reach the necessary size for proofing, the maximal format of screens is limited. Typically, the common screen diagonal has a maximum of 30" (76 cm). With a 22" (56 cm) flat screen, two A4 pages can be completely displayed, see Figure 31, and for examples, see Table 2.
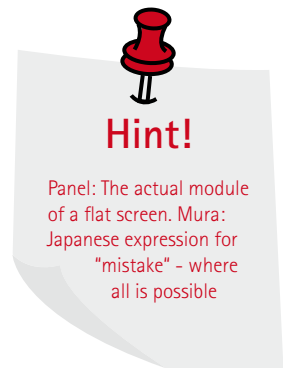
For large images, the uniform reproduction over the entire screen is of great importance. Ultimately, it should make no difference whether a picture is displayed in the left upper or right lower corner. In Figure 32, a software, in which the homogeneity of a monitor can be evaluated, is shown.

The objective assessment of the level of uniformity is subject to ongoing research. Here image distortion on a micro and macro scale come into play such as Mura. Currently the human eye is the best judge for any kind of homogenity problems. The shown 3x3 assessment is a good starting point and gives a first, general idea.

Figure 31: Example of a monitor with a wide display

Hint!

Panel: The actual module of a flat screen. Mura: Japanese expression for "mistake" – where all is possible

Diagonal	Aspect Ratio	Pixel Matrix	Size [cm]
19" / 48 cm	5:4	1280 x 1024	37.7 x 30.1
20" / 51 cm	4:3	1600 x 1200	40.8 x 30.6
21" / 53 cm	4:3	1600 x 1200	43.3 x 32.5
22" / 56 cm	16:10	1920 x 1200	47.4 x 29.6
24" / 61 cm	16:10	1920 x 1200	51.9 x 32.4
26" / 66 cm	16:10	1920 x 1200	54.9 x 34.3
30" / 76 cm	16:10	2560 x 1600	64.6 x 40.4

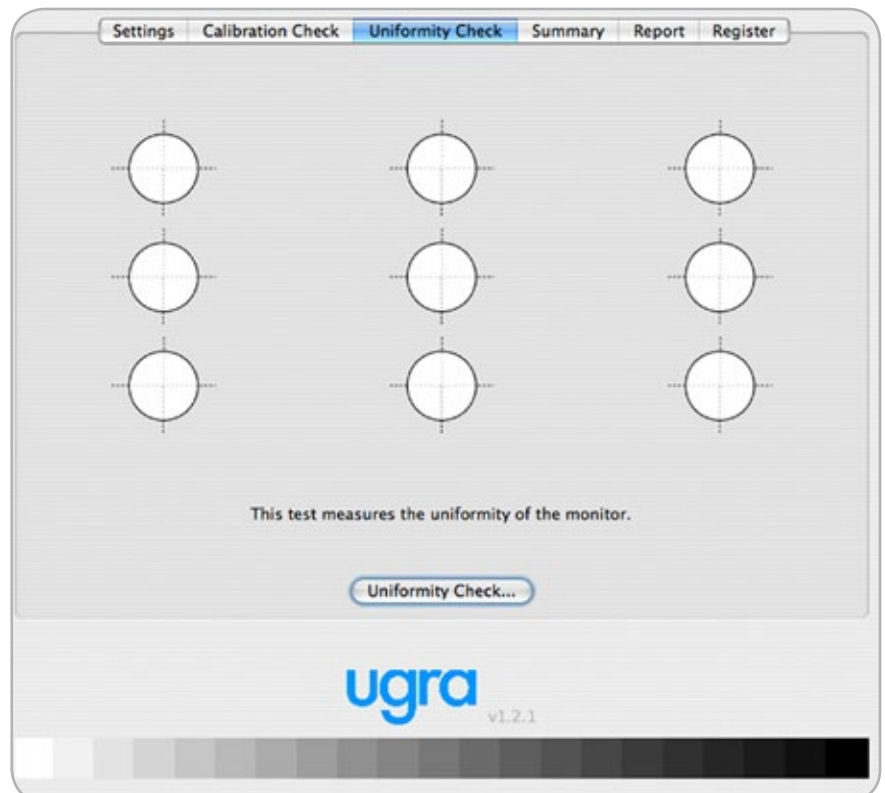Table 2: Typical sizes and accompanying solutions of LCD screens

Figure 32: Capture of a homogeneity measurement

Colour Gamut

Another important characteristic of a monitor is its colour gamut, which is fundamentally made of the primaries, in a 3 channel display (red, green and blue) and the white point. These are determined in flat screens through the interaction of the background illumination and transmission through the filter. For all printed colours to be simulated, the proofing system must include the colour gamut to be simulated completely or at least show a gamut warning.

In a digital proofing system, the gamut is determined mainly by the combination of ink and paper. With screens, this depends on the related phosphors (CRT) or the interplay of colour crystals (LCD) and the background illumination. Both tube and flat screens can exceed the print gamut in some colour areas. However, in some cases, not all of the „print colours" can be represented, especially in saturated yellow and cyan-blue areas.

The colour gamut of offset printing on paper is indicated in Figure 33 (orange colour). A typical LCD monitor covers the offset printing gamut to a large degree.
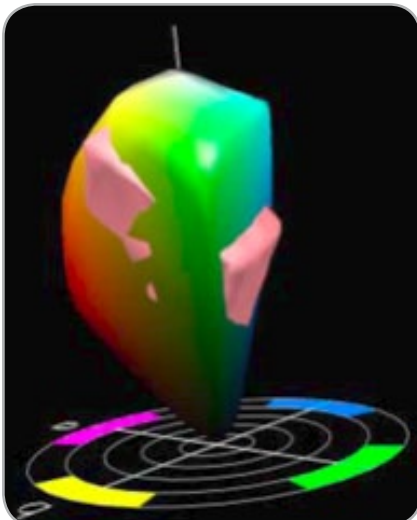
Wide Gamut Displays

These displays provide an even larger than sRGB colour gamut, which has the ability to display allmost all colours of the standardized offset presses (e. g. represented by FOGRA39). Some examples of wide gamut display models are listed in Table 3.

Contrast

One aspect of the colour gamut is the contrast ratio, which is expressed through the luminance ratio of white and black point. The contrast should be at least 200:1. This serves as the standard characterization for monitors and is based on measurements in a darkroom.

Brightness

The brightness of a display is determined by the measurement of the luminance and indicated in cd/m^2. In order to obtain the same colour appearance between the illuminated paper in the booth and white area on the screen, the typical illumination level should be between 400 and 500 lx, and the luminance should be between 150 and 200 cd/m^2. This is clarified in more detail in Chapter 1.7.

Hint!

Luminance: white = 100 cd/m^2 and black = 1 cd/m^2 makes a flare level of 1%

white = 101 cd/m^2 and black = 2 cd/m^2 makes a flare level about 2%.

Figure 33: Comparison of a screen (shown in natural colours) and an offset printing colour gamut (shown in red)

Label	Image
EIZO CG 221 Diagonal 22"	
EIZO CG 241 W Diagonal 24"	
EIZO CG 301 W Diagonal 30"	
QUATO IP Intelli Proof 213 Diagonal 21,3"	
QUATO IP Intelli Proof 260 Diagonal 25,5"	

Label	Image
NEC Spectra View 1990 Diagonal 19"	
NEC Spectra View 2090 Diagonal 20"	
NEC Spectra View 21 Diagonal 21"	
NEC Spectra View 2190 Diagonal 21"	
NEC Spectra View 2690 Diagonal 26"	

Table 3: Example monitors for graphics art by EIZO, NEC and QUATO (February 2008)

Stability

A second factor that is sometimes underestimated in a hard- or softproofing system is the local and temporal stability. The reproduced colours must be constant over the entire sheet and/or screen within narrow tolerances. The change of the CIExy chromaticity coordinates during warm-up is shown in Figure 34. Typically, a stable condition is obtained after about one hour. According to monitor type, the warm-up time may be different. Therefore, it is recommended to calibrate the monitor after a warm-up of two hours.

The visual appearance of a proof/softproof must be the same when evaluated to a later time (e.g. days later). Problems can be avoided by daily checks of the calibration. If needed, a recalibration should be performed. In practice, you should review and/or repeat the monitor calibration at least once a month.

Viewing Angle Dependency
(not viewing angel ;-))

An fundamental disadvantage of LCD monitors is still its dependence on viewing angle. Due to the display technology, luminance and colour can change with the viewing angle. This deviation of the perfect reflecting diffuser is to this extent critical because even in a fixed viewing position, as the outer corners of the screen are already seen under an angle of about 20°. When head movements or several observers that view the image simultaneously come into play the viewing angle dependency becomes even more critical, see Figure 35.

Measurements by the Fogra show that current high-quality LCD screens, suited for softproofing, show colour deviations of ΔE 2.5 that exist at about 20° to 30° viewing angle, see Figure 35.

It is important to note that the stated contrast ratio values found in product brochures are determined for a minimal contrast of 10:1. However, this statement gives no information about the colour variation with varying viewing angle!

One can judge the viewing angle very well with different test images; for example, a process grey vignette, or subjects with skin tones.

Further characteristics

Further important characteristics are not focussed on in this handbook include additive mixture failure as well as the reflectivity of the screen surface.
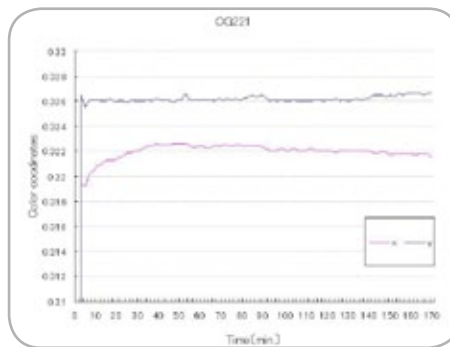
Figure 34: Variation of the CIExy colour values in the warming up of a screen (EIZO CG221)
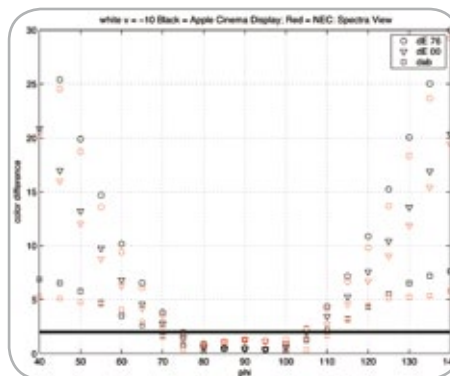

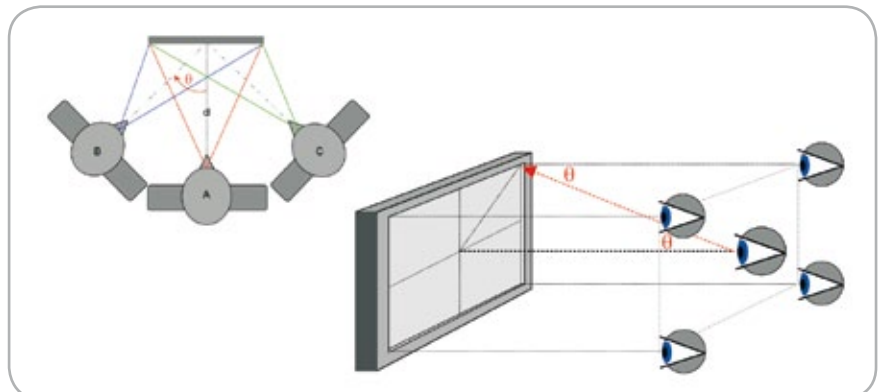Figure 35: Display of colour deviations due to viewing angle

Figure 36: Viewing angle situations in the softproof area

1.7 Viewing Conditions: Evaluation of "Standard Lighting"

Requirements for Ambient Illumination

Illumination plays an important role in the colour comparison between original and reproduction. The perception is determined by the spectral radiance of the light and the adaptation of the eye. The adaptation is influenced by the background and surrondings of the object which are in the field of view. The background is the area adjacent to the sample. Again, colour stimulus is characterized through the interplay of the spectral distribution of the light and the reflectance factor of the object. The influence of different types of light on the colour appearance is displayed in Figure 37.

ISO Standards Define Guidelines for visual appraisal

For the colour comparison of print and proof, as well as for the comparison of print and monitor basically two ISO standards have emerged. These standards serve as the guide for the daily colour appraisal practice in the graphic arts industry. These are ISO 3664:1996 "viewing conditions for the graphic technology and photography" and ISO 12646:2008 "graphic technology – displays for colour proofing – characteristics and viewing conditions".

The ISO standard 3664 determines the criteria and corresponding tolerances for the viewing booths used for critical colour appraisal in the graphic arts industry. It should be noted that ISO 3664 defines two levels with respectively adapted demands and tolerances. On the one hand, the critical comparison between two prints, "ISO viewing condition P1", and on the other hand, the practical appraisal for less critical work, "ISO viewing condition P2". The criteria of "P1" is considered to be a "superset" of "P2". That means that each viewing booth which fulfills the narrow tolerances for "P1", also automatically fufills that for "P2". Items evaluated include:

- Chromaticity
- Visible range metamerism index MI_{vis}
- Ultraviolet range metamerism index MI_{UV}
- Minimal colour rendering index
- Minimal illuminance and homogeneity
- Neutral background and diffuse surface reflectance
- Requirements for practice such a hour meter indicator when the lamps should be replaced

Figure 37: Identical test prints under three different light sources (left: commerical flourescent, middle: D50 Simulator, right: incandescent)

Importance of the Background (Ceiling Illumination)

Colour appraisal with standard light booths seldom take place in totally darkened rooms. Normally, there is a general level of illumination. At the same time, this concerns also the colour appraisal without use of standard light booths. The resulting mixture of light (booth illumination and room illumination) affects the sample area as well as the screen and therefore, influences the final colour rendering. The latter is particularly relevant for light booth on or at press stations, which is not typically equipped with a light shield.

Neutral Wall and Ceiling Paint

The wall paint next to the ceiling lights plays an important role. Only a small portion of the light output by the lamp encounters the print sample directly. A large portion is reflected by multiple surfaces, where a colored (spectrally selective) surface will change the light colour corresponding to the reflection properties. The floor and pieces of furniture can also have a negative influence.

Ergonomics?

The assembly of softproof working stations in the vicinity of outside illumination (or even window) should be avoided. A perfect shielding of the changing daylight phase (from the sunrise to the sunset) is ideal. The monitor should be alligned parallel to the window. This assures that no light from outside will disturb the user (no psychic blending/dazzling). Also reflections are avoided on the monitor screen (see Figure 38).
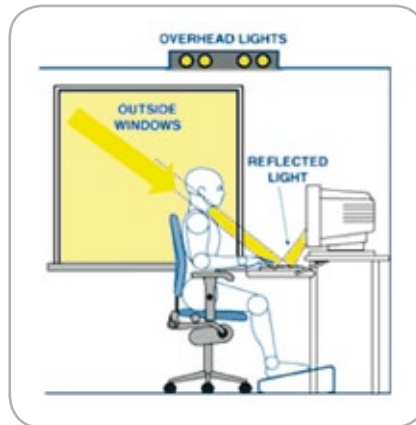

Figure 38: Optimal monitor placement:
The parallel alignment of the monitor to the window is good practice, but should be not near a window if possible. Blinds to stop outside light are not shown in this illustration, but are needed.

Tip!
Viewing distance should be about as large as the screen diagonal.

2. Softproofing Settings in Software Programs

In the following, basic recommendations are outlined that should help you in the use of the pertinent programs. In general, we recommend the use of "branch profiles". For example, for working colour spaces, profiles such as ISOcoated_V2 as a CMYK working colour space and ECI RGB as a general RGB working colour space. These colour management settings are normally set in a way that profile mismatches will result in a warning message and the number of colour transformations are minimized.

Special ICC "checker" profiles help to test whether a program or operating system honors the monitor profile for the image to be rendered. Such a test profile can either swap the colour channels or it can be constructed in such a way that all colours are reduced to a single colour. On the Fogra webpage, you can find a CMYK profile, which, when applied to a picture, will output only red colours. A similar RGB test profile is supplied, which will only show green colours. (http://forschung.fogra. org/index.php?menuid=62)

To test if your application honors the source profile, just load this picture "Rot wie die Liebe" (which is a German saying and means "Red like love" or "Roses are red"). If the source profile of the picture is honored, the picture will be shown in red colour. If not, it will be shown blue (see Figure 39) . Note that this test only helps you to determine, if a monitor profile is used at all. It gives no information how accurate a monitor profile is.

As noted, these settings can deviate in individual cases. However, in practice, they have proved themselves to be well-made. The dialogue box in older Photoshop versions can be adjusted accordingly.

Figure 39: False colour profile (so called checker profiles)

Attention!

The choice of absolute colorimetric rendering intent (RI) assures that the info palette shows the correct CIELAB values. Be aware that colour conversions via mode changes will use the rendering intent defined in the colour settings too ("Image > Mode > CMYK"). Colour conversions should always be done via „Edit > Convert to profile" to have maximum control. Also when importing documents in InDesign the default conversion options will be used. Therefore it might be needed to switch rendering intent to perceptual or relative colorimetric (with or without) black point compensation.

Adobe Photoshop CS4
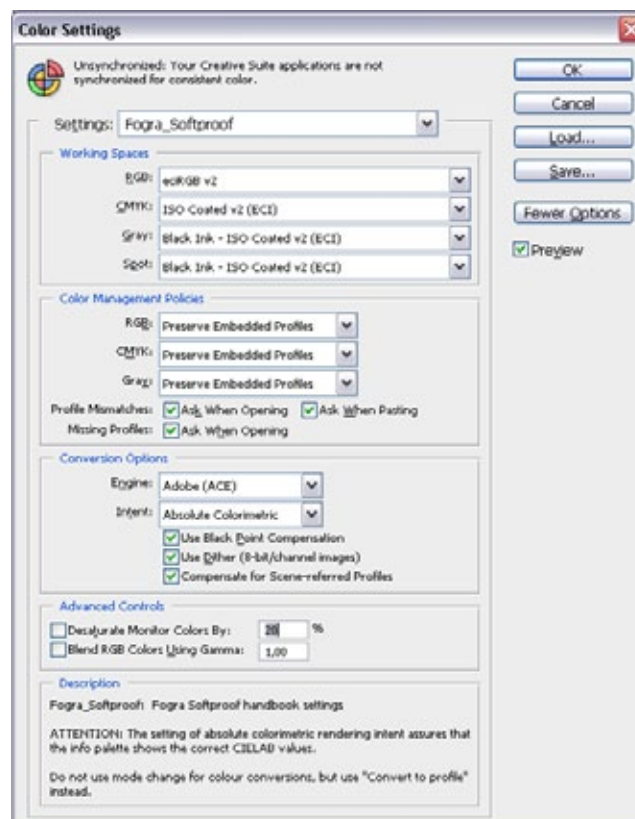
Figure 40: Recommended colour settings in Adobe Photoshop CS4

Hint!

This csf file is available on the Fogra website for downloading.

Quark XPress

XPress is being tested at the present time with respect to its softproofing capacities. Basic review and settings for softproofing with Quark XPress are planned for the next version of this handbook.

Adobe InDesign CS3

It is assumed that all CMYK files placed in the layout were prepared already for the intended printing condition and need no more conversion.

Older Versions

InDesign 3 (CS1) does not offer the option to preserve numbers under the colour management guidelines. Therefore, InDesign CS1 was to be set in a way that the source profiles are retained, see Figure 42. An unwanted CMYK-to-CMYK transformation is avoided when the placed CMYK contents are already separated (converted) for the intended printing condition and the same profile is assigned to the document.
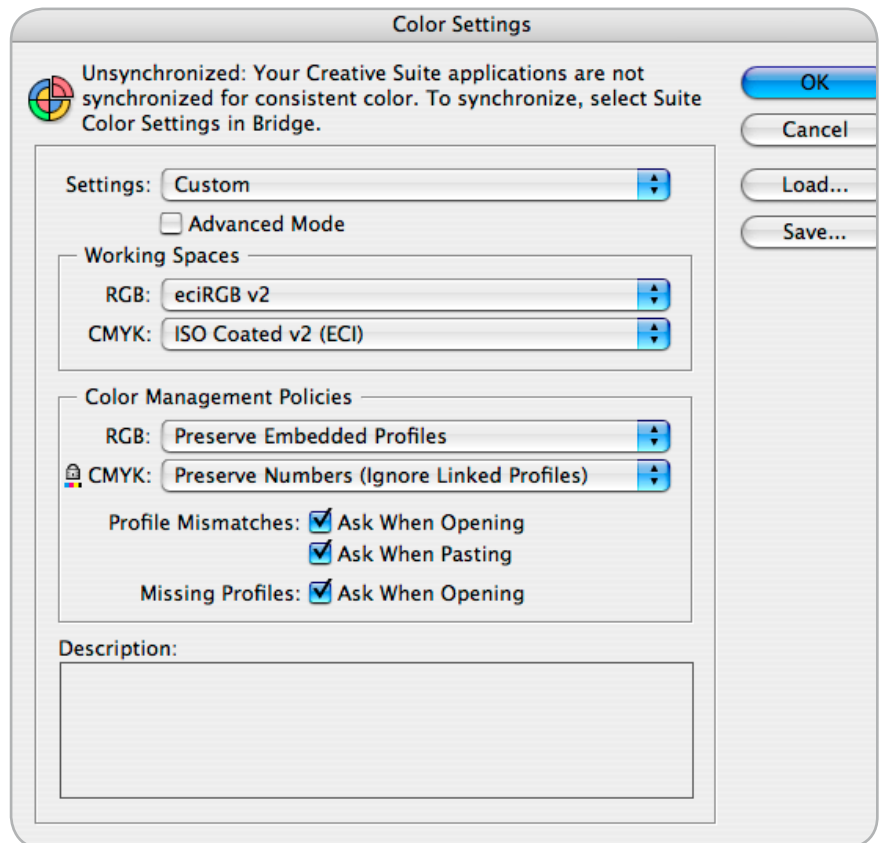
Figure 41: Recommended colour settings in Adobe InDesign 5 (CS 3)
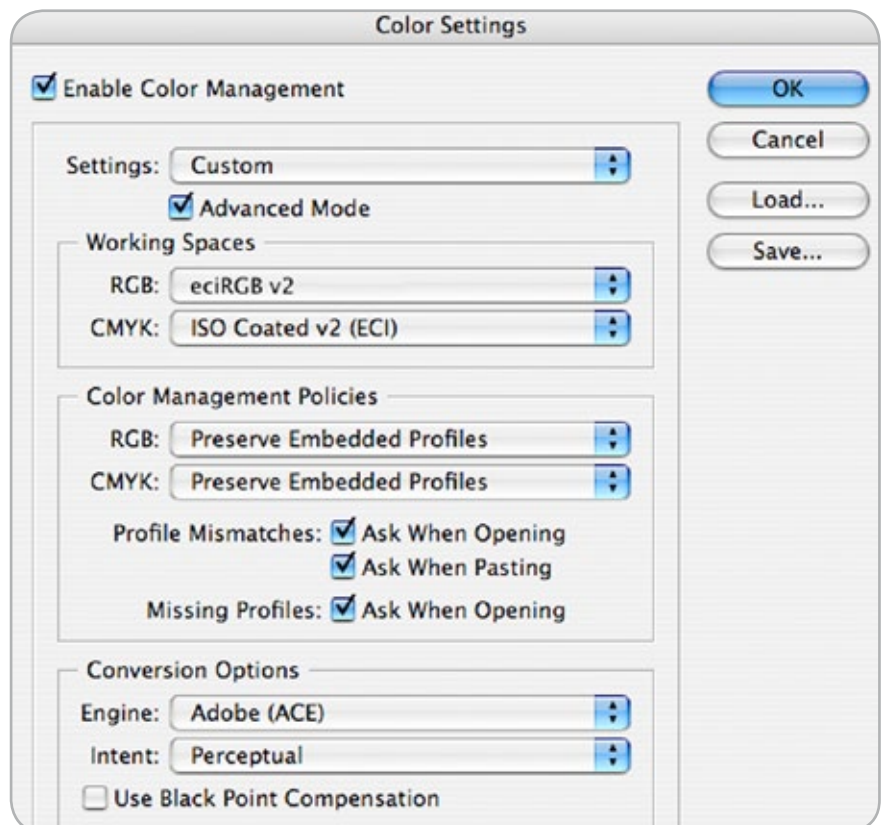
Figure 42: Recommended colour settings in Adobe InDesign 3 (CS 1). The setting choosen is "Preserve embedded profiles"

Adobe Acrobat Professional
In Acrobat Professional, there are two places where to alter the colour settings. For colour management, the working colour spaces are determined here, see Figure 43. In order to guarantee conformity for PDF/X-files, one should take note that the option Output Intent overwrites the active working space.
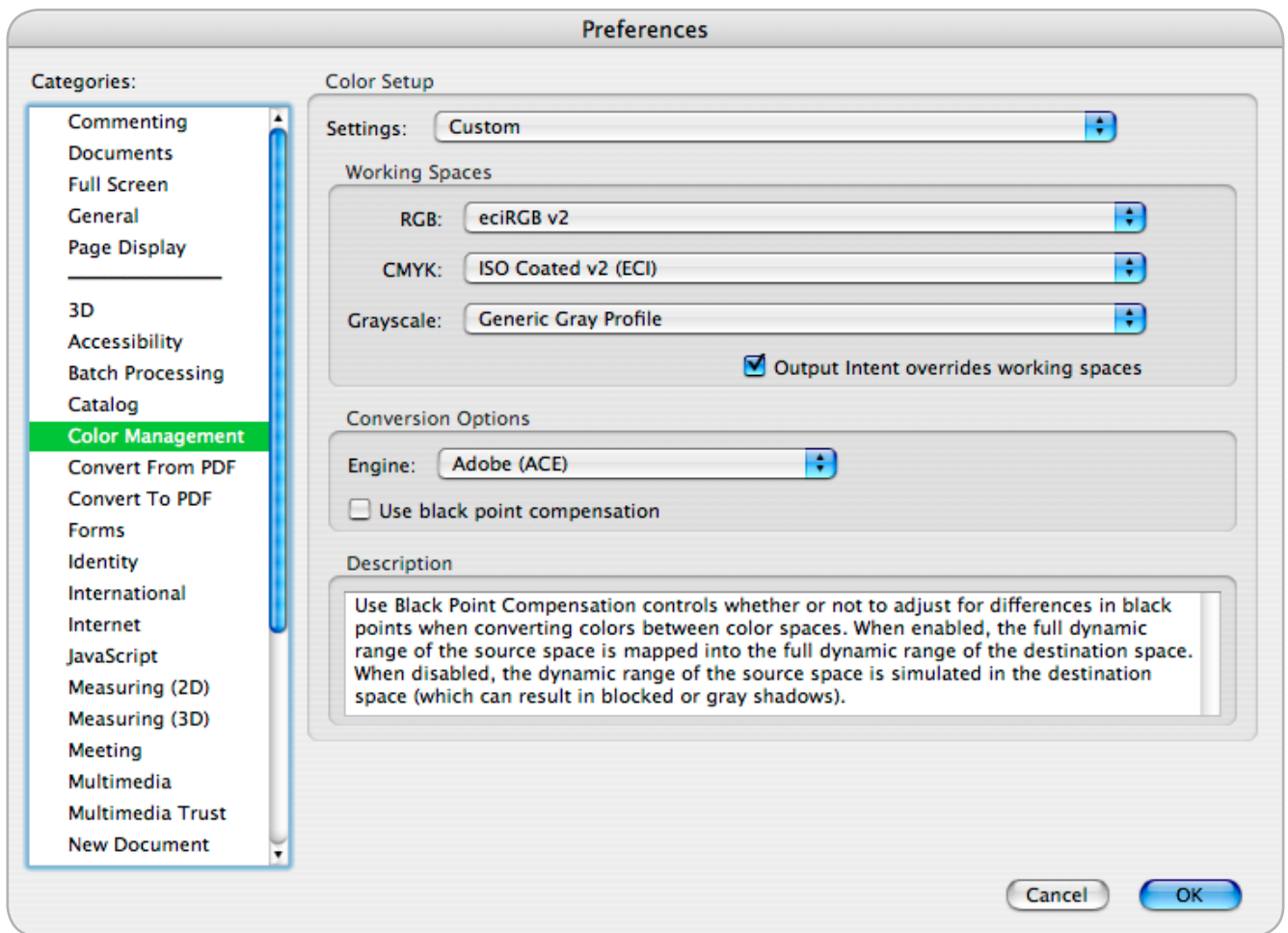
Figure 43: Recommended colour settings in Acrobat Professional 8.0

Under Page Display, there are settings
that will also determine the representa-
tion of files on screen, see Figure 44.
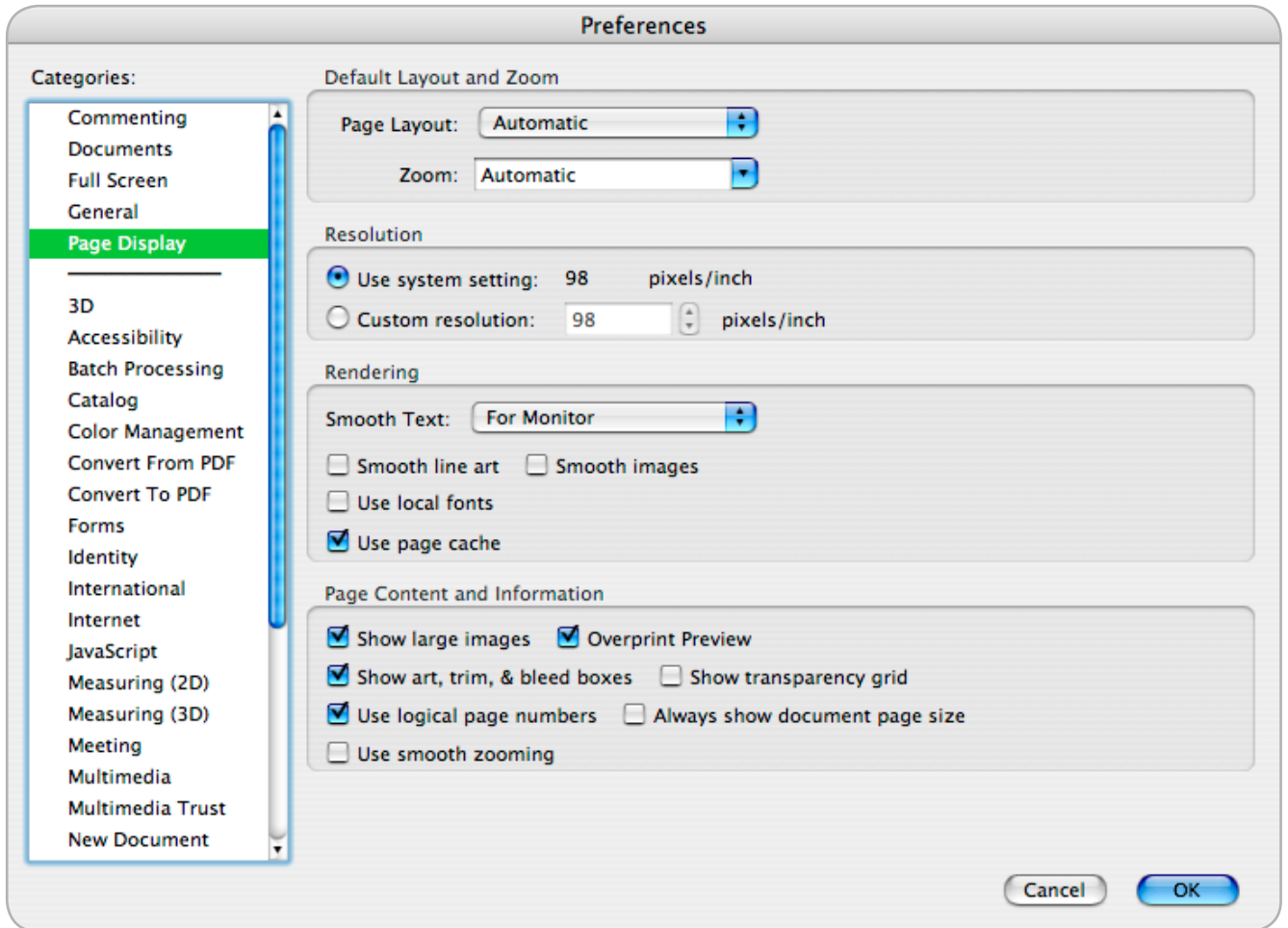
Figure 44: Recommended items to review for the display in Acrobat Professional 8.0

3. Calibration: Step-by-Step

The explanations in Chapter 1.3 about calibration, characterization, and profiling can be supplemented by this section in a more detailed, but general form. Here, we explain the general concepts, while on the Fogra web page manufacturers of monitor calibration solutions describe the specific settings and options accordingly (http://forschung.fogra.org/index.php?menuid=19). In this chapter, we explain all possible parameters that could be altered. If a calibration program does not provide the ability to alter a specific attribute explained in this chapter (e.g. very few programs and monitors allow measurement and then adjustment of the gamma setting manually), the setting has to be ignored by the user.

Target Settings: Luminance, White Point (Colour Temperature) and Gradation (tonal scale)
A basic goal of a calibration is a perceptual uniform differentation of available lightness levels. Also, the technical features of a device should be used in a way that the target settings are achieved, and the colour rendering of the device is not limited in any way. The best choice of target settings is dependent on the actual use case. The third use case "softproof at the press control station" is not explained here, since more experiments have to be conducted.

Luminance
In the case of the comparison of a print sample to a screen, a luminance match between the paper white in the booth and white displayed on the screen is the goal. This is obtained through an interactive adjustment of the luminance control of the booth (dimmer) and the luminance control of the screen (the control is often labeled "brighness"). For typical illumination levels about 500 lx, a luminance of about 160 cd/m^2 is the prerequisite of a good lightness match. The calibration can be done visually and/or by means of measurements. It should be noted that the monitor should not be adjusted to its maximum luminance because over time the maximum achievable luminance of all displays will degrade.

In a "Photographer Workflow", it is good practice to adjust the luminance to a level of 160 cd/m^2. According to the ambient illuminance level, however, a lower or sometimes a higher luminance can also be appropriate. In a "Photographer Workflow" a good monitor luminance is achieved when white areas on the desktop or in an image don't look greyish, and also, the lightness of the image is not unpleasant or "blindingly" high. If the ambient illumination level changes, the monitor luminance should also be adjusted accordingly. By dimming the background illumination of flat screens (in the OSD, On Screen Display menu) the luminance can be adapted by many monitors without severely affecting the accuracy of the monitor ICC profile.

White Point (Colour Temperature)
The white point is usually adjusted first. For a hardware calibrated display, the white point and other parameters are set automatically. In a software calibration, red, green, and blue are regulated as the three channels by gradation curve corrections on the graphics card.

To find the best target white point, activate the softproof in your application and use an absolute rendering intent for the display (in Adobe applications this is achieved by choosing the option "Simulate Paper White"). Then, test which white point setting will give you the best match of the white in the softproof to the white of the paper stock. To find the best setting you can try to calibrate to different target colour temperatures or target white points (xy). Some monitor calibration solutions offer a tool to visually fine-tune and recalibrate the white-point.

A colour temperature (CCT) in the range between 5000 to 6000 K might be optimal. Many users prefer values between 5300 and 5800 K. The calibration to a target white point which differs from 5000K is not wrong, but takes into account that the eyes perception of a self-luminous monitor might be perceived somewhat different to an illuminated unprinted substrate having an own coloration. This is due to the partly unknown „mechanics" of chromatic adaptation. A tolerance measured of ±100 K is often not critical for the white point. In the "Photographer's Workflow", the white point can be selected somehow freely because the eye adapts itself to the white point. However, here, the white point should fit the environment. As a rule, a white point between 5000 and 6500 K is perceived as neutral.

Hint!

Further information on the gamma settings can be found on page 37.

Hint!

A low illumination level is recommend. This helps to achieve a stable adaption to the monitor white point. Furthermore it minimizes distracting influences of a somewhat colored illumination (if present).

Gradation
Next, the gradation of the colour channels is adjusted by red, green, and blue. The functional relationship between digital input value and resulting output value (e. g. luminance) is often designated as a gamma function.

It is common to use a gamma setting between 1.8 and 2.4 (see Table 4). Here, also lies the so-called CIEL* calibration, whereby the above corresponds to the lightness function defined in the CIELAB encoding space.

	Colour Temperature	Gamma/Gradation	Comment
Adobe-RGB	6500 K	2,2	
Apple-RGB	6500 K	1,8	
ECI-RGB	5000 K	1,8	
ECI-RGB V2	5000 K	L*	
Photogamut	5000 K	2,2	optimized for print gamut
ProPhoto-RGB	5000 K	1,8	extremely large
sRGB	6500 K	sRGB (~ 2,2)	Standard for office documents and amateur devices
ISOCoated_V2	P1 (ISO3664)		CMYK standard colour space for offset printing

Table 4: Colour temperature of white point and tone response of typical colour encodings.

		"Photographer's Workflow"	"Reproduction Workflow"
Colour Settings	Luminance (brightness)	160 cd/m²	1. Luminance adjustment with blank paper in cabin 2. 160 cd/m²
	White point (colour temperature)	5800 K	1. Colour adjustment with blank paper in booth 2. 5000 K
	Gradation (tone value curve)	1. CIEL* 2. Gamma = 1.8 3. Gamma = 2.2 4. Gamma = sRGB	1. CIEL* 2. Gamma = 1.8
Monitor Settings	Type	LCD and/or CRT	
	Calibration	Hardware calibration (if not possible, software calibration)	
Profile Settings	Type (size)	16 Bit (large)	
	Chromatic Adaptation	CAT02 (from CIECAM02)	

Table 5: Target values for typical softproof applications.
Please be aware that those target values should not be seen as „the Fogra recommendation", but to be used as a starting point if one is unsure which values to choose. See the Fundamentals section of this handbook and the recommendations in the text how to find the best target values for your setup.

General calibration procedure

1. Examination of the Surroundings
To examine this, both neutral grey wall paint and general illumination with a colour temperature of about 5000 K are required. Furthermore, there must not be any colorful items or other objects, such as post-it notes for comments, in the visibile field of the viewer. Some calibration programs offer the functionality to measure the ambient light. With this, the colour temperature and the illumination level (measurement of the illuminance in lux) can be estimated.

2. Warm-up Phases and Cable Connections
Let the monitor sit for about two hours after it is turned on. Be sure that the optimal signal connection exists (digitally rather than analog) and the communication between computer and monitor is guaranteed, for example with DDC (by means of a suitable DVI cable) or USB cable. If required, calibrate the measuring instrument when the software asks for it.

3. Definitions of the Target Settings
Start the calibration software, and determine specifications in accordance with Table 5 and/or the ambient light measurements. Start the calibration.

3.1 Hardware Calibration
When monitors with incorporated corrections are used (e.g. correction curves for red, green, and blue), no further intervention of the user is necessary because all correction steps needed have been automatically performed by the software.

Definition of White Point:
The lightest neutral colour that might serve as a reference for the colour adaption. Expressed in CIEXYZ (where Y indicates the luminance).

Definition of Black Point:
The darkest neutral (CIExy colour coordinates of the white point) colour. This may require an average of several measurements due to measurement noise.

3.2 Software Calibration (Manually Supported)
If the monitor does not support hardware calibration, all parameters should be adjusted by means of the controller and tuners at the monitor. The remaining inaccuracies will be compensated in the further calibration with the help of corrections to the graphics card.

3.3 Software Calibration
If the screen offers no substanial control possibilities, a software calibration must result, which the user does not have control of.

4. Storing the Monitor Profile
After the calibration and profiling is complete, name the monitor profile with a suitable filename. It is recommended to include the following: monitor type, date, and target values in the form of luminance, white point, and tone value curve. For example, 160_D50_Lstar or 120_D55_18.

5. Visual Examination
A visual examination is recommended. Some calibration solutions offer options to fine-tune the calibration. This can be achieved by means of the monitor LUT or the graphics card LUT or by measuring a visually optimized whitepoint which is used in a second calibration as the new aim white point. To fine-tune a calibration use a display program with ICC colour management (e.g. Adobe Photoshop), and review the representation based on a reference image (e.g. offset print sample with its specific simulation profile). Then, by means of the available correction possibilities (gradation curves and/or white point), match the screen image with the reference print sample in the viewing booth. Finally, depending on the options of the calibration software, recalibrate and/or replace the original profile with the new profile.

Tip 1!
For the mixture of white and black wall paint, it should be noted that the resulting colour should be tested for its neutral colour appearance. Example: Measure a paint sample with the EyeOne Pro. Target value: $L^* = 38 - 82$, $C^* < 2$

Tip 2!
Deactivate all screen savers.

Tip 3!
During and after the calibration, a Fogra test image can be used for visual inspection of the monitor. Download at: www.fogra.org

Hint!
The black point is not always the darkest colour possible (similar to offset print), so that a higher contrast can be obtained (e.g. darker black value). It must be decided in the individual case between the neutrality of the depths and contrast.

Hint!
DVI-I can also transmit analog signals.

Advice for visual adjustments

If you perform a fine visual djustment of the calibration, it is very important that you are confident that your reference print is of high accuracy. In many cases a visual fine-adjustment is not needed. But for highest quality an experienced user can make use of visual fine-adjustments. Be aware that altering the monitor or graphics card LUT can introduce banding in gradients which should look smooth. If possible a recalibration to an optimized target white point should be preferred.

6. Proper Technical Examination (Validation)

In examination of the monitor, device independent values (RGB) are sent via the display profile to be tested to at the screen. The resulting colour is measured and compared to the desired values (that the generated ICC profile predicts). From that, colour differences are calculated and shown for judgment of the calibration's quality.

7. Regular Calibration

After the calibration of the softproof station, the question remains of when to test the calibration. In the beginning, at least a weekly inspection should result by means of the visual and/or technical test.

4. Hands on: Softproofing of RGB and CMYK Images with Adobe Photoshop

In this chapter, there are examples both for the "Photographer's Work-flow" and "Reproduction Workflow" in Adobe Photoshop 9 (CS2). While in the "Photographer's Workflow", the soft-proof shows the colours of an RGB file which is yet not prepared for a printing condition, while in the "Reproduction Workflow" a softproof simulates a prin-ting condition. Configure Photoshop in accordance with the basic settings described in Chapter 2.

Dialogue Boxes:
The "Softproof Control Center" where you can customize the proof condition for the softproof is found under the menu „View > Proof Set-up", see Figure 65 and Figure 66.

Hint!

Photoshop does not always indicate all Display Options (on screen). This depends on the profile characteristics of the involved ICC pro-files and the number of channels to be softproofed.
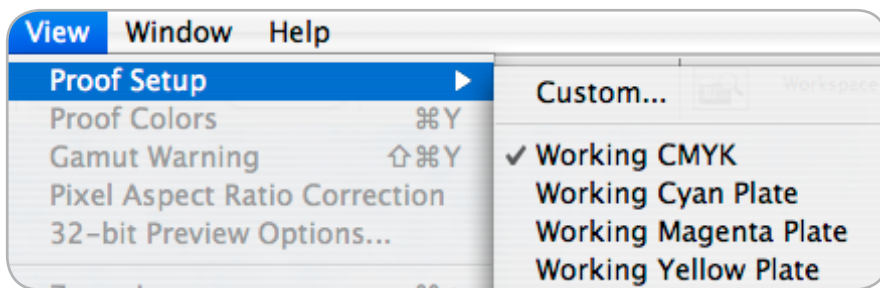

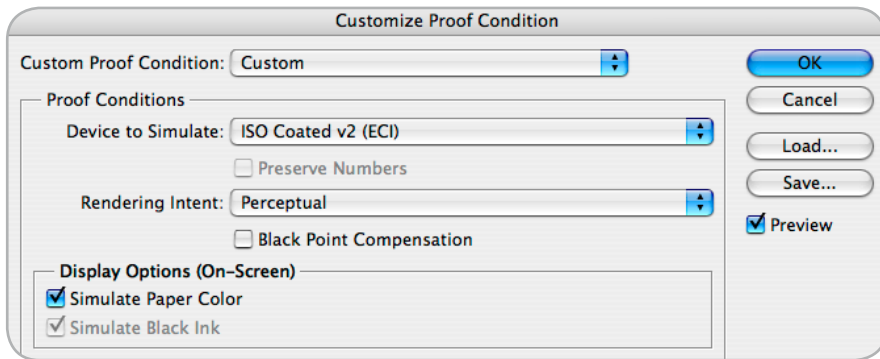Figure 65: The "Softproof Control Center" in Photoshop

Figure 66: Softproof settings: Image separation („data processing") options and settings for the rendering to the screen.

Tip!

Please note the separation of „Proof Conditions" where the conversion options are set and the „Display Options (On-Screen)" to configure the output to the display.

**Colour Transformation:
"Photographer's Workflow" versus
"Reproduction Workflow"**
When the colour (pixel) values of the
file should be shown bindingly — this
is a typical scenario for a photographer
who wants to know "which colours
are in the file". Therefore the colours
of the file (image encoding) have to be
converted absolute colorimetric to the
monitor. This is reached with the cur-
rent monitor profile being adjusted to
simulate the device, see Figure 67.

To simulate how the data file looks on
a specific output device, the data has
to be converted for this output device.
Then, the converted data is displayed
absolute colorimetrically on the display.
This task exists both in the "Photogra-
phers Workflow" and "Reproduction

Workflow". To achieve this, the ICC
profile of the device is selected as the
simulation profile, whose colour result is
being tested. Please note that this will
only work up to Photoshop CS1 for RGB
encoded pictures when using the Adobe
CMM (or ACE). For CS2 and greater this
functionality can be achieved with the
Apple or Windows CMM.

Another possibility is to bypass proces-
sing (separation). In this case, the RGB
or CMYK colour values of the image file
are sent directly to the simulation pro-
file and followed by an absolute colori-
metric representation. This shows how
a file will come out on a specific device
if no prior colour conversion has been
done. Figure 69 displays this example
with a CMYK image.

Hint!

Figure 67: Colours out-
side of the screen gamut
are cut off ("clip-
ped").

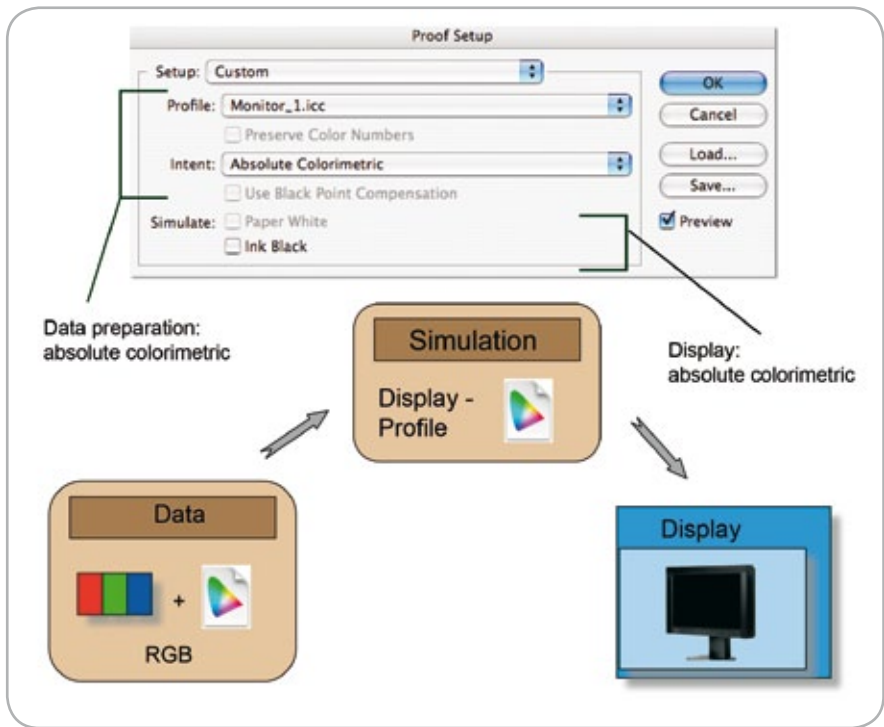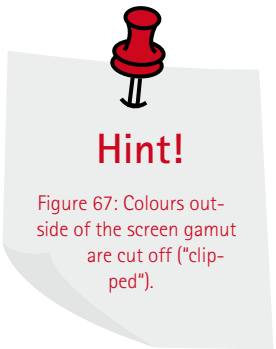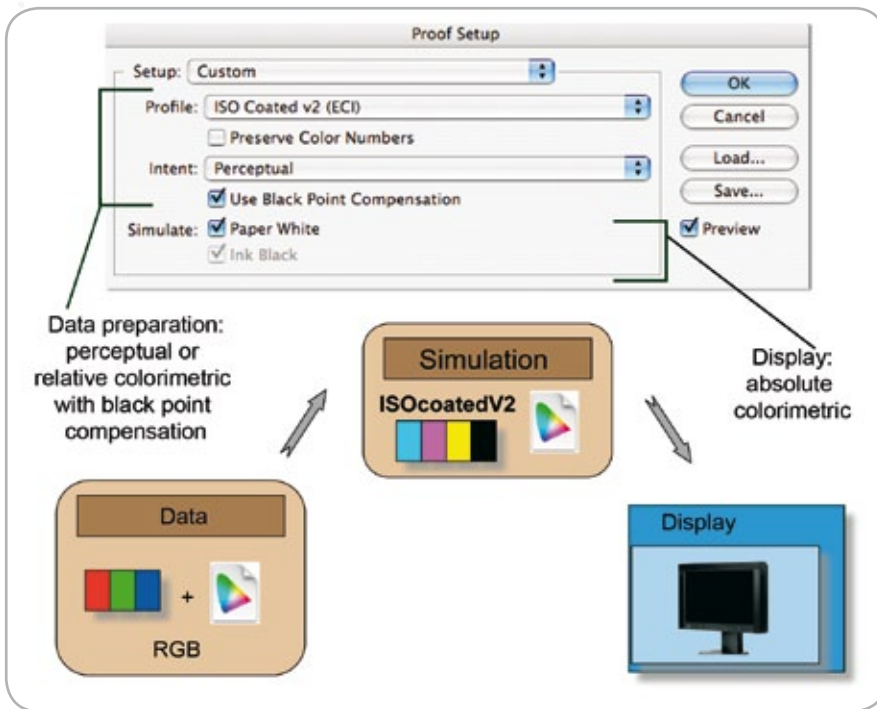Figure 67: Colour transformation: "How does my data really look?"

Figure 68: Colour transformation: "How does my file look when processed with a perceptual intent in respect to ISOcoated_V2?"

Hint!

Figure 68: Relative colorimetric with black point compensation is also common for image data conversion ("separation").
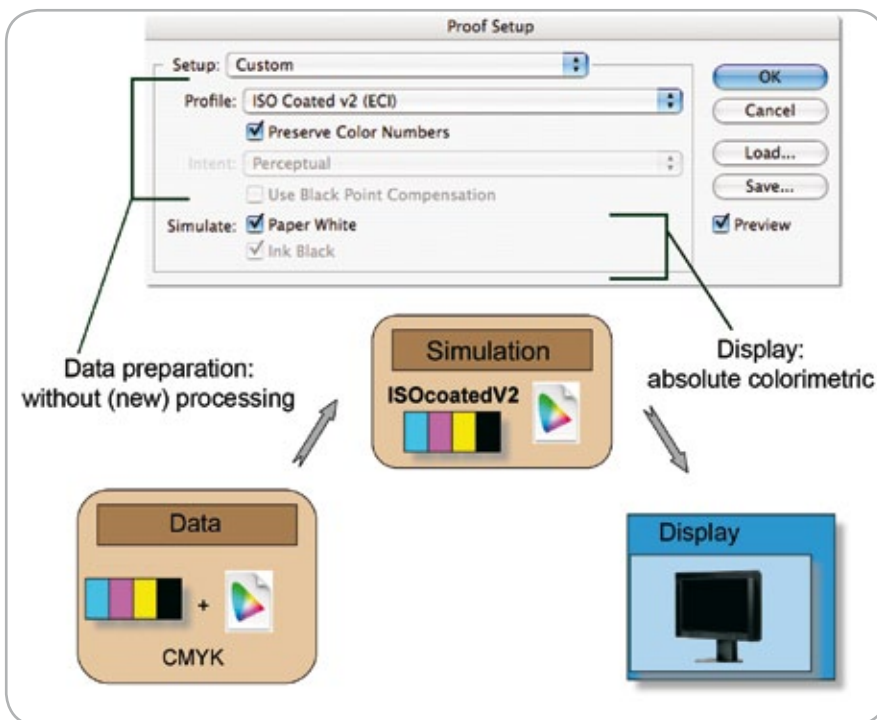
Figure 69: Colour transformation without new processing and absolute colorimetric representation.

5. Fundamentals and Concept Explanation
5.1 Description and Measurement of Light (Photometry)

The measurement of light forms the base for an exact representation of the original scenery. Herewith, the fundamental measurements are to be referred to as "luminance", "illuminance", "luminous intensity", and "luminous flux". For digital photography, the illuminance, as well as the luminance, are of importance, which are described in the following section. In light measuring, one distinguishes between light measurement and object measurement. Light measurements characterize the properties of a self-emitting light source. Object measurements describe the properties of the light that is reflected from an object.

Luminance, L
The luminance L, is correlated with the subjectively perceived lightness and brightness of self-emitting light source or an illuminated area. The unit of the luminance is Candela per m^2 (cd/m^2). The luminance should not be confused with the lightness. To determine the luminance of a light source, for example, a floodlight, you must divide the luminous intensity (cd) of the lamps in viewing direction by the projected area in m^2 which is seen (light measurement). The luminance of an object, which is not self-emitting light, is calculated from illuminance E in front of the object and the coeffecient of reflection ρ (so-called object measurement).

Equation 1

$$L = \frac{(E \cdot \rho)}{\pi}$$

This simple calculation assumes that the illuminated object reflects the incoming light perfectly and diffuse. By Equation 1, it is clear that with a well-known luminance and illuminance, the coeffecient of the reflection can be calculated. With the same illuminance, the luminance of an object with large "ρ" is higher than with a smaller reflection.

Illuminance, E
In contrast to the luminance, which describes the light intensity thrown back by the object per area, the illuminance, "E", indicates how brightly the object is illuminated. Therefore, it concerns a light measurement. The unit of the illuminance is the Lux (lx).

Equation 2

$$E = \frac{\varphi}{A}$$

where
φ is the luminous flux
A is the illuminated area

The luminous flux of a light source indicates how much light is issued into all directions of the surrounding room. The unit of the luminous flux is the Lumen (lm). The illuminance is divided in half with the square of the distance to the light source (double distance: ¼ of the illuminance). Over how many orders of magnitude, the illuminance can vary in the daily life, is illustrated in Figure 72.
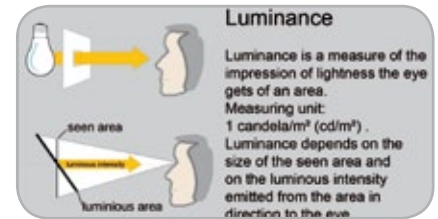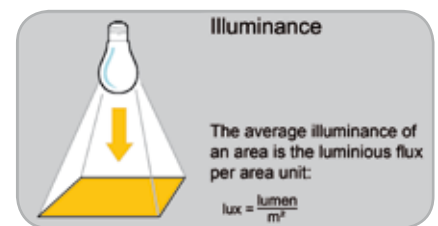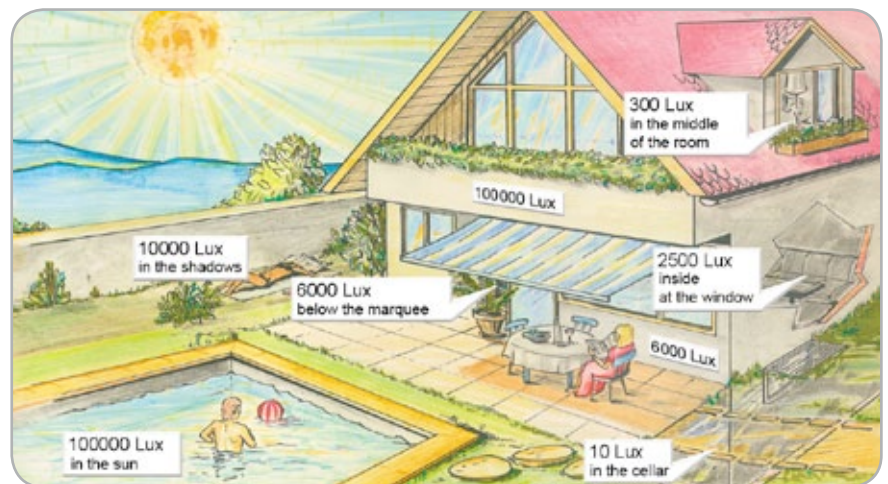

Figure 70: Luminance

Figure 71: Illuminance

Figure 72: Typical illumination levels.

Exposure, H

The light quantity which influences over a certain period, t, of an area is called exposure. It is, therefore, the product out of illuminance and time or luminous flux multiplied by time divided by area.

Equation 3

$$H = E \cdot t$$

The exposure is represented often in a logarithmic scale. The task of the photographer or the automatic exposure control mechanism is to select the exposure time dependent on the light surrounding to the camera and the reflection of the object to be photographed, so that all important details can be captured. The exposure is determined by the time and illuminance. This is adjusted over the opening aperture (aperture stop or f-stop) in the lens. It is referred to as the aperture number or aperture stop, K.

Equation 4

$$k = \frac{f'}{D}$$

where
k is the aperture number
f' is the focal length of the lens
D is the diameter of the aperture

In the establishment of the aperture number, k, it is meaningful to obtain a duplication or halfing of the incoming light with every change of k. Such a variation of the aperture opening by a factor of 2 makes a required change of the aperture diameter by a factor of $\sqrt{2}$. For this reason, aperture numbers are even powers of square root of 2 (1; 1.4; 2; 2.8; 4; 5.6; …).

Colour Stimulus

The physical spectrum, which is received by a human observer or a technical image capturing device indicates the colour stimuli.

5.2 Illuminant, Chromaticity, and Correlated Colour Temperature

In supplement to the prior section, the spectral power distribution (SPD) of the light source is discussed in the following, as well as chromaticity, colour temperature, and colour rendering index.

The illuminant (tabulated data) or light source is described by the relative spectral radiation distribution of a light source, which is comparable to the spectral reflection factor of non-luminous colour. Therefore, it represents a comprehensive colorimetric description of primary light sources. For measurement, a spectroradiometer is necessary, which is expensive and often only found in larger laboratories. The Figure 73 shows a spectra typical for common illuminants.

The spectral peaks of 410, 450, and 550 nm exist due to the gas discharge in the mercury steam, which represents the base for light creation in fluorescent tubes. Dependent on the composition of the gas mixture, there are two essential types: HMI and HTI. The HMI lamps posess a large colour rendering index, while the HTI lamps have a high luminance. Table 6 explains the abbreviations.

Chromaticity and Colour Temperature
The chromaticity of a light source or an illumated object is specified as chromaticity coordinates x, y. Tristimulus values, which differ only through luminance (CIE Y) from one another, have the same chromaticity. The plot of all chromaticity coordiantes of the spectral lights (only emitting at one wavelength) will result in a horseshoe type diagram. The chromaticity coordinates CIEx = 0.3457 and CIEy = 0.35854 represent for example the chromaticity of the illuminant (CIE) D50.

Colour Temperature
The "temperature" of the colour of a light source is determined by how it compares to the colour of a "black body". This is an idealized hollow body, for example out of platinum, that absorbs all light that falls on it. If a "black body" is heated, it glows and emits light. At the same time, it passes

through a colour scale of dark red, red, orange, yellow, white to the light blue. The corresponding curve in the chromaticity diagram is named Planckian locus, see Figure 74. The unit of the colour temperature is named Kelvin (K), occasionally also called "degree Kelvin".

In practice, it is very rare that the CIExy of light sources (e.g. displays) lie exactly on the Planckian locus. In this case, one indicates the so-called correlated colour temperature (CCT). It is described in the standard DIN 5033-8. Both the colour temperature and the correlated colour temperatures say nothing about the spectral power distribution, but rather serve only as a indication whether a colour is more reddish, neutral, or blueish. The light of lamps of the same light colour (colour type of the light type) can have a clearly different spectral composition and can evoke, therefore, also a clearly different colour rendering.

Colour Rendering Index (CRI)
The colour rendering index serves as the numerical indication of the colour rendering characteristics of a light source against a reference light source. With this, a colour test procedure is used, which determines and values the colour shift between the tristimulus values under the reference and the test illuminant. The colour difference is to be calculated in a perceptual uniform colour space. The standard DIN 6169 defines, for example 14 colours and the UVW colour system to calculate the colour difference. Based on the colour difference found for each test colour, the general colour rendering index, Ra, is calculated after an empirically determined relation, see Equation 5.

Equation 5

$$R_a = 100 - 4.6 \cdot \Delta E_i$$

For the determination of a special colour rendering index, other test colours can be used, if necessary. Both the test colours and the colour difference formula used to have to be stated.
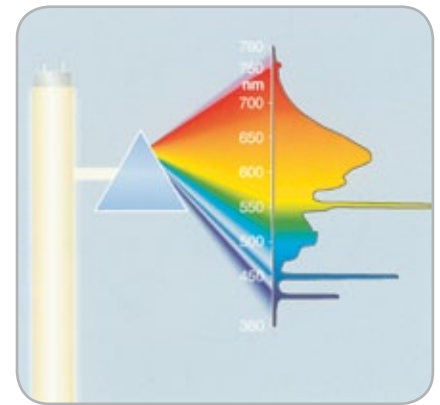
Figure 73: Spectra of a fluorescent bulb:

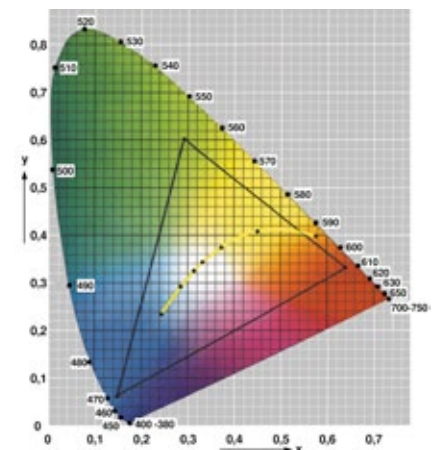| Abbr.	Meaning
H	Mercury (Hg)
I	Iodide, Bromide (Halogen compound)
M	Base metals (Alkaline earths: Holmium, Dysprosium)
T	Daylight

Table 6: Symbols of gas mixtures in lamps

Figure 74: Chromaticity cooardinates of the "black body" (dotted line) and chromaticity coordiantes of a RGB system (defining the gamut as shown in the triangle).

5.3 Gamma and its Disguises

Most likely, the largest uncertainity in prepress is the concept of "gamma". Aside from the photographic gamma, which describes the section of the linear part of the exposure vs. density chart, we encounter several definitions of that term in the digital prepress area. The characteristic correlation between the control voltage and the tube current of a CRT screen is often called "monitor gamma".

Under the assumption that the analog-to-digital converter and the reaction of the phosphors are linear with respect to the electron current, it can be said that the monitor gamma is also the connection between digital colour value and optical quantities, such as the luminance. It is also designated as a "system gamma" because it describes the total system out of computer, software, graphics card, and monitor. Such a "system gamma," also applies to LCD monitors, but here there is no "electron gun".

"Gamma" serves as the exponent in Equation 6 or the slope of the transfer function of these quantities in a two-fold logarithmic representation (Equation 7).

Equation 6

$$\gamma = X^{\gamma}$$

Equation 7

$$\gamma = \frac{\lg Y}{\lg X}$$

where
Y luminance, normalized to 1
X for example normalized (1) R, G or B
   value of the input signal
γ is the monitor gamma

A representation of common tone values and gradations curves is represented in Figure 75.

Which "gamma" is the best?
If a job was calibrated and profiled, then the choice of the gamma value plays only a secondary role. The characterization, for example by means of an ICC monitor profile, guarantees the complete description of the display independent of how gamma was adjusted. Therefore, how an image looks on a Windows PC with a gamma of 2.2 should look about the same on all calibrated and profiled monitors. It is even similar to a calibrated Mac monitor with a gamma of 1.8.
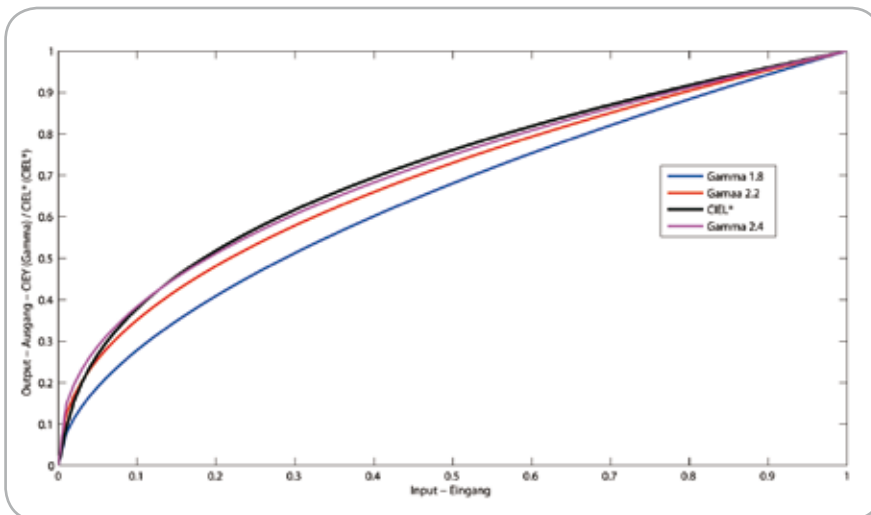

Figure 75: Representation of different gamma values, as well as CIEL*.

5.4 Matrix or LUT (Lookup Table Profile)

Matrix Transformation

The matrix-based transformation with a tone value reproduction curve (TRC) is used if the device to be characterized (e.g. a screen) shows a linear behavior between device dependent control values and the resulting colour values. For maxtrix profiles the CIEXYZ colour space is used as the PCS ("Profile Connection Space") instead of CIELAB, because CIEXYZ scales linear with intensity. Matrix-based profiles have a small file size, which is about 4 to 8 KB. Consequently, they fit well for the definition of a working colour space. With the use of matrix profiles, it is esay to achieve that equal RGB combinations (grey balance) will also always be rendered neutrally. The connection between the device dependent RGB colour value and the PCS is represented with the matrix model in Figure 76, whereby the calculation is possible in both directions.

In Figure 76 the RGB values are to be linearized by gradations curve (TRC) and subsequently subject to be converted with a 3x3 Matrix into the XYZ coordinate of the PCS. For the reverse, to achieve linear RGB values the XYZ tristimulus values are converted with the inversed 3x3 Matrix . The device specific RGB values result after applying the inversed TRC curves to the linear RGB values.

LUT Transformation

The multi-stage conversion with LUTs is described in the following:

- for every input channel, a tone value reproduction curve
- a multi-dimensional table
- for every output channel, a tone value reproduction curve
- additional matrices in specific V4 profile tags

For example the conversion from a colour encoding space with 3 primaries, e.g. ECI-RGB, to an encoding space with 4 primaries, e.g. ISOCoated, can be imagined as a cube with many grid points [Figure 77].
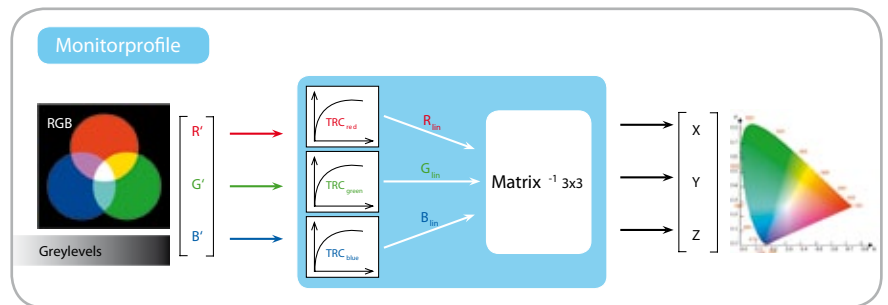

Figure 76: Schematic representation of the matrix transformation in an ICC profile (Source: Fama Skript)
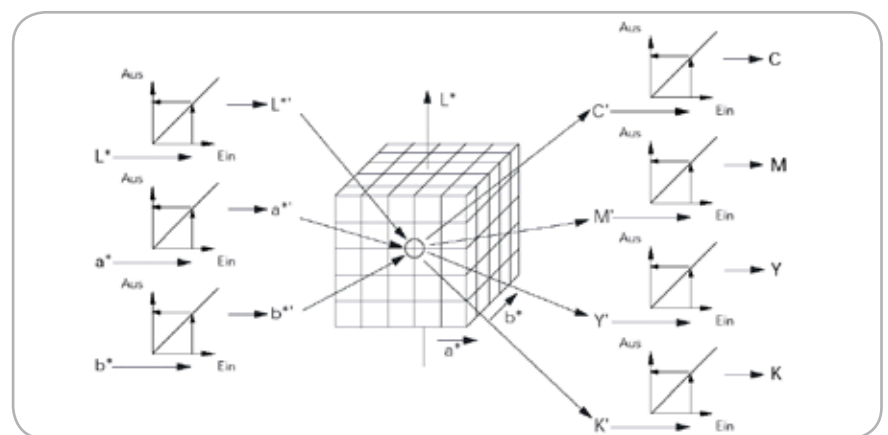

Figure 77: Conversion with a multi-stage transformation

In this example the conversion from RGB values to CIELAB is done first by means of a source profile. For every grid point in CIELAB encoding the corresponding CMYK aim values are stored. The RGB code values R=G=B=128 are converted to CIELAB values [$L^* = 61$, $a^* = 0$, $b^* = 0$]. As described above a matrix/TRC transformation by means of ECI-RGB profile is used in this case.

The separation with perceptual rendering intent of the ISOcoated profile is specified in the BtoA0 table. In the example the following CMYK values result: [C = 38, M = 30, Y = 28, K = 11]. For CIELAB values that do not lie on a grid point, the CMYK values are interpolated. The interpolation is done by the CMM. The CMM is normally integrated into the operating system. Figure 77 illustrates the conversion sequence when the tone reproduction curves (TRC) of the input and output are not altered. The CIELAB values are used in the three-dimensional colour look up table (CLUT). The figure illustrates how the resulting

CMYK values for a sample colour are calculated.

PCS: Profile Connection Space

TRC: Tonevalue Reproduction Curve

CMM: Colour Matching Module

Information

München, Oktober 2007

Überprüfung Ihrer Abmusterkabine gemäß ISO 3664 – unabhängig und kompetent

Die kritische Abmusterung von Farben ist für die tägliche Produktion in der grafischen Industrie von hoher Bedeutung. Fehlurteile aufgrund einer falschen Beleuchtung führen fast zwangsläufig zu Reklamationen und damit zu erhöhten Kosten im Produktionsprozess. Die ISO-Norm 3664 definiert hierfür verschiedene Kriterien hinsichtlich der Gütesicherung für die farbverbindliche Abmusterung. Beurteilen Sie Ihre Farbe korrekt und zuverlässig und lassen Sie dafür Ihre Abmusterkabine von der Fogra überprüfen.

Gemäß ISO 3664:2000 prüfen wir:

¬ Farbwiedergabe [allg. und spezieller Farbwiedergabeindex]
¬ Farbwiedergabe [Metamerie-index MI_{vis}]
¬ Korrekter UV-Anteil [Metamerie-index MI_{UV}]
¬ Farbgenauigkeit [D50]
¬ Homogenität
¬ Umfeldbeschaffenheit
¬ Wartungsvorrichtungen

Durchführung & Dauer der Prüfung:

¬ ½ Tag vor Ort [nach Terminvereinbarung]
¬ Ergebnisbericht innerhalb der folgenden 3 Wochen

Scrutiny of your viewing cabinet according ISO 3664

Since deficiencies in light sources and viewing conditions, and inconsistencies between colour viewing facilities, can distort the colour appearance of substrates, reproductions and artwork, they are likely to cause miscommunication about colour reproduction and processing. Ask Fogra for objectively testing the specifications for illumination and viewing conditions that, when properly implemented, will reduce errors and misunderstandings caused by such deficiencies and inconsistencies.

Based on ISO 3664:2000 we check your cabinet with respect to:

¬ Colour rendition [general and special colour rendering index, CRI]
¬ Colour rendition [CIE visible range metamerism index – MI_{vis}]
¬ Correct UV energy [CIE UV range metamerism index – MI_{UV}]
¬ Colour accuracy [D50]
¬ Homogeniety
¬ Ambient conditions
¬ Maintenance

Duration of the test:

¬ ½ day at the vendors premise [after appointment]
¬ written report within 3 weeks

Kosten

EUR 1.500,– zzgl. MwSt.
Für Fogra-Mitglieder
[30 % Rabatt]
EUR 1.050,– zzgl. MwSt.
zzgl. Reisekosten

Preise gelten für maximal 4 Kabinen bzw. 4 verschiedene Beleuchtungsszenarien [z. B. verschiedenen Beleuchtungsniveaus, Lichtfarben, variabler UV-Anteil, ...]

Übersetzung: zzgl. EUR 200,–

Costs

EUR 1.500,00 excl. VAT
For Fogra members
[30 % discount]
EUR 1.050,00 excl. VAT
Travel costs to be added

Prices for a maximum of 4 cabinets or 4 different illumination set ups [e. g. illumination levels, illuminants, variable UV-content, ...]

Translation: EUR 200,00 extra

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Praktische Abmusterungsbedingung für den SoftProof [Color Communicator der Firma Just Normlicht].

Practical viewing conditions for soft proofing [Color Communicator of Just Normlicht].

ISO 3664:2000 Betrachtungsbedingungen für die graphische Technologie und die Photographie.
ISO 3664:2000 Viewing conditions – Graphic technology and photography
Bezug/How to get: Beuth-Verlag, Berlin, www.beuth.de