

Color Management

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Color Management

The goal of color management is to make images look the same regardless of the hardware or platform used to capture, view or print them. Without color management, colors can change significantly when images are captured, viewed, or printed. A well-configured color managed work flow helps you get consistent color across all your devices subject to the limits of their differing abilities to reproduce images. While color management can be a little intimidating at first, most of the work is in setting it up. Once configured, you can largely forget about it and still be confident of achieving consistent results that make good use of the color capabilities of your equipment.

ICC Profiles

Color management is based on ICC profiles—files that describe the characteristics of a device such as a scanner, digital camera, monitor or printer. Profiles are created by carefully measuring the colors of standard color test targets with a spectrophotometer and processing this data using specialized profile creation software. A cross-platform standard for encoding color profiles has been defined by the ICC (International Color Consortium) and adopted industry wide. For more information on color profiles, see the ICC web site at <http://www.color.org>.

Profile Types

There are several different categories of ICC profiles, but the three common types are scanner profiles, monitor profiles and printer profiles. As you might expect, scanner and printer profiles are used to characterize image input and output devices. Monitor profiles serve a dual function—they can be used to define the characteristics of a specific monitor or they can be used to define the properties of a color space. A color space profile is a precise definition of the meanings of the numbers that make up red, green and blue layers of a color image. Associating a color space profile with an image removes any ambiguity about the colors represented in the image.

Gray Profiles

While color profiles get most of the attention, there are also gray profiles. Gray profiles are used with black and white images and consequently they contain less information than color profiles. In fact, a gray profile is pretty much just a white point, a black point and a curve. Even so, it is useful to assign gray profiles to black and white images if only to define their gamma as there are two competing standards: 1.8 and 2.2 and using the wrong gamma distorts the tonality of the image. There are also several standard dot gain profiles that lighten shadows to varying extents. These are intended to cancel out the tendency of certain printing presses to output shadows that are too dark because ink dots spread out when they are absorbed into the paper.

Custom Profiles

In many cases, the scanner, monitor and printer color profiles you need are supplied by the manufacturer, so you don't need specialized equipment and software to create custom profiles to get good results. On the other hand, there are good reasons to create your own custom profiles:

- The characteristics of a given color device can change over time because of variations between different batches of printer paper and inks, aging of scanner light bulbs and monitor phosphors etc., and these variations can cause inconsistent color.
- You may wish to experiment with papers or inks that are not currently supported by a printer vendor or use a scanner or monitor that does not come with a profile.
- The only definitive way to calibrate a monitor to match specific standards is with specialized hardware and software.

Profile Files

By convention, color profiles have the extensions: *.icm* or *.icc*. Under all recent versions of Windows, profiles are stored in the following folder:

C:\Windows\System32\Spool\Drivers\Color

Picture Window only recognizes profiles stored in this system profile folder.

Profiles are listed by their internal descriptions as opposed to their filenames. The profile description is embedded within the profile and is usually more informative than the filename. To view the description of a profile you can click on it in Windows Explorer with the right mouse button and select *Properties* from the popup menu, and then click the *Profile Information* tab.

Color Gamuts

Each device has its own color gamut which is simply the range of colors it can capture, display, or print. An RGB color space is the set of all colors you can generate using any possible combination of red, green and blue values in an image.

Scanners and digital cameras generally have relatively wide color gamuts—determining the actual gamut is difficult and not necessarily well-defined, so thus this information is seldom if ever reported by the manufacturer.

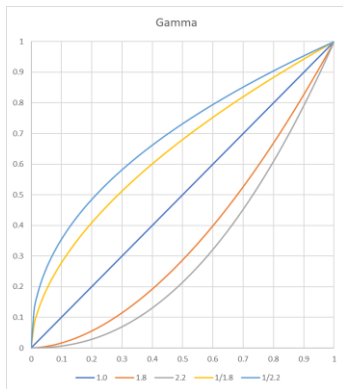
Monitors have been improving gradually over the years. Most reproduce all or most of the sRGB gamut which is the television and web standard. Better models reproduce most or all of the Adobe RGB color gamut or the DCI-P3 gamut.

Inkjet printers typically have a color gamut that largely overlaps the monitor gamut but there are colors monitors can display that are unprintable and printable colors that cannot be displayed. Monitors reproduce bright, highly saturated colors better than printers (especially red, green and blue) while printers reproduce dark highly saturated colors (especially cyan, magenta and yellow) better than monitors. Both can reproduce less saturated colors accurately. Certain colors such as intense cyan, blue and violet (e.g. deep blue skies or purple flowers) are particularly hard for printers, even with a high-quality profile. Printers also have a much more limited dynamic range than scanners, digital cameras or monitors because of the relatively low contrast ratio between solid black and paper white. Contrast depends heavily on the ink and paper you use. Printing with dye-based inks on glossy paper usually produces the most saturated colors and the richest blacks because dyes tend to be very intense and the shiny coating prevents them from being absorbed into the paper. Printing with

pigment-based inks on uncoated paper generally produces less saturated colors and weaker blacks because pigments are not as intense and some of the ink gets absorbed into the paper. Different combinations of inks and papers have their own unique looks and different subjects may print better with the brighter, snappier look of glossy paper or the softer, more muted look of matte paper, so it pays to become familiar with the different effects you can achieve with different media.

Gamma

A set of gamma curves represent how the image data in an RGB image file translate into measured screen brightness for each color. A gamma curve is represented as an exponential relationship which approximates the response of the human visual system. In this case, the gamma curve is described by a single number which is the exponent value. In Microsoft Windows, a standard gamma of 2.22 is the most commonly used value, and this is also the standard used for the web, video and most monitors. The prepress standard is gamma 1.8 which more closely approximates the characteristics of a printing press.



White Point

When you see light reflected from or transmitted through something, you are viewing object color. When you look at a light source such as a lamp or a neon sign, you are viewing self-luminous color. To understand the difference, suppose you display a large yellow square on a computer monitor—you would perceive the image as yellow. Next, suppose you illuminate a sheet of white paper with the same yellow light. Even though the same yellow light is reaching your eyes, you may perceive the paper as white since you intuitively understand that the yellow color of the paper is due to the light, and you compensate automatically. If you view the yellow light reflecting from the paper through a small opening, you would again perceive the color as yellow since this removes the visual cues that let you infer the true color of the paper. In most cases, the human visual system is very good at figuring out the colors of objects regardless of the illumination, but in doing so it alters the perceived color of the image it receives.

The white point of a monitor is the color you get when you display white on the screen (white is defined as the color you get when you set R, G and B to their maximum values). Daylight is typically in the range from 5000°K to 6500°K, and most incandescent and halogen lamps are between 2600°K and 4200°K (see Monitor Calibration below for a lot more information on

color temperature). When you observe a scene, your eyes and brain quickly analyze and cancel out the effects of different white points. When viewing prints, the light reaching your eye comes from the light source illuminating the print and is reflected off the surface of the print and therefore the color you see depends on the color of the light. Different light sources (such as direct sunlight, indirect sunlight, incandescent light bulbs, fluorescent light bulbs and halogen light bulbs) all have different spectral characteristics. For the purposes of color management, these real-world light sources are represented by idealized standard illuminants.

To get a close match between colors on your monitor and prints, the white point of your monitor should more or less match the color of the light illuminating the print. The white point of a print is the color of the viewing light reflected by the paper the image is printed on. If the monitor white is significantly different from the print viewing light there will be an apparent color shift between the monitor and the print. If the monitor color temperature is higher than the color temperature of the viewing light, an image viewed on the monitor will have a blue color cast compared to a print made from the same image. If the monitor color temperature is lower, the image on the screen will look more yellow than the print.

The most commonly used white points are D65 and D50. D65 approximates sunlight and has a color temperature of around 6500°K—this is the standard illuminant used in the sRGB color space (the Windows default color space), as it looks somewhat brighter on a monitor than D50. A D50 white point has a color temperature of around 5000°K and is the prepress standard. While images displayed on a D50 monitor are a less brilliant and more yellow than with D65, in you may achieve better color matching between your CRT and prints using a D50 white point for your monitor, depending on the light you are using to illuminate the prints.

When comparing prints to images on your monitor, it is important to control the color of the light used to illuminate the print and to avoid casting stray light onto the monitor screen. One of the best ways to accomplish this is to use a commercial viewing booth which is simply a box open in the front and illuminated by internal color-corrected fluorescent lights.

Unfortunately, commercial viewing booths are expensive and bulky. A less inexpensive alternative to a viewing booth is the OttLight TrueColor. Available as a desk or floor lamp, it includes a color-corrected bulb with a color temperature of around 5500°K. Just make sure you place the light behind your monitor and dim the room lights so that stray light does not hit the face of the monitor.

RGB Color Spaces

The set of colors that can be represented by combinations of a specific set of primaries, along with a white point and a set of gamma curves defines a monitor color space, also called an RGB color space.

For monitors and other devices that work by simply adding together primary colors, the color gamut is well represented by a triangle with its red, green and blue primary colors each at a vertex. These primary colors are in turn determined by the physical properties of the monitor.

The Windows default color space is called sRGB. This color space has a gamma of 2.2 (with some minor adjustments to very dark colors), a D65 white point and color primaries that correspond closely to standard CRT phosphors. While sRGB is a good choice for creating

images for use on the web, and video production, its color gamut omits some of the most intense colors that color film, scanners, and digital cameras can capture and that printers can reproduce.

Rendering Intents

Since every device that handles color has its own unique characteristics, even the best color management system cannot make an image look identical on each one. ICC profiles support four different methods for resolving mismatches between color spaces. The method it uses is determined by the rendering intent you specify.

Rendering intents are a property of the individual ICC profile and many profiles only support a single default rendering intent. Rendering intents apply mostly to printer profiles. If a profile does not support rendering intents, it simply ignores them.

For purposes of illustration, let's call the original color space A and the color space we are converting to B. The four ICC rendering intents are:

Maintain Full Gamut

This is also called picture intent or perceptual intent and is the default you should normally use with photographic images. When you use this rendering intent, the full gamut of color profile A is stretched or compressed to match the full gamut of color profile B. This guarantees that all colors in both profiles will be available, but some colors that could be matched perfectly because they lie within both color gamuts may be altered slightly.

Preserve Saturation

This is also called graphic intent or saturation intent and is designed for working with charts and business graphics. When converting colors, this intent preserves the saturation of colors in profile an image at the expense of changing their hue and brightness in some cases. This rendering intent is not intended to be used for photographic images.

Preserve Identical Colors and White Point

This is also called proof intent or relative colorimetric intent and preserves colors that are within both color gamuts and preserves the white point of the image. Colors in the input image that lie outside the color gamut of the output image are changed to the nearest matching color. This gives the most accurate possible match for colors within both color profiles but may result in loss of color detail in areas outside the gamut of the input or output images.

Preserve Identical Colors

This is also called match intent or absolute colorimetric intent and preserves colors that are within both color gamuts but does not preserve the white point of the image. Otherwise it is identical to proof intent (see above).

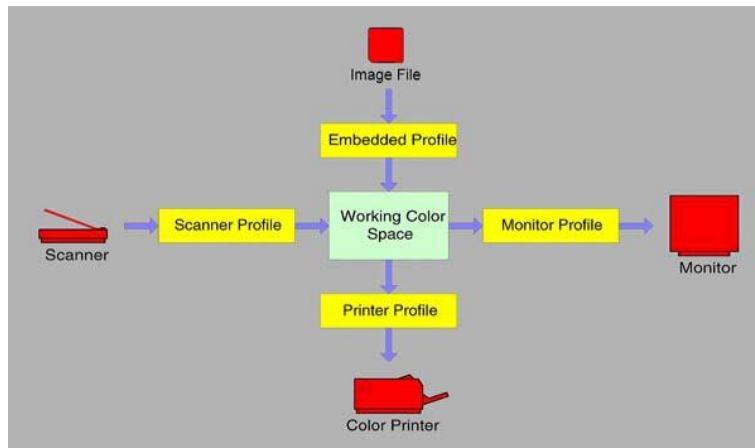
Working Color Space

While not strictly necessary, it is strongly recommended that you convert images on input to a standard working color space. This is the RGB color space to which you convert images when you open them or scan them, in which you edit your images, and from which images are

converted when you print them. The working color space is selected from the Color Management dialog box. There are three good reasons for using a Working Color Space:

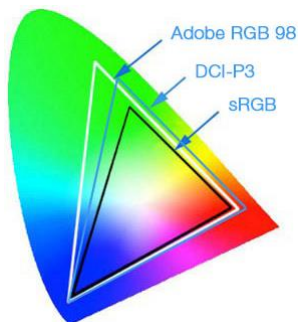
- If all your images are not in the same color space, this can lead to unexpected color shifts when combining images as the meaning of the RGB image data changes depending on the color space. In fact, Picture Window issues a warning if you attempt to combine images with different color profiles.
- Converting images to the working color space irons out any nonlinearities in the original device's color space yielding standard RGB data. This in turn makes image editing operations more accurate.
- There are performance advantages to working in a standard RGB color space since it is easier to translate to the monitor and printer color spaces.

The following diagram illustrates how Picture Window translates image data from one color space to another via the working color space:



Choosing a Working Color Space

The following is a list of the color profiles included with Picture Window that you can use for working color spaces:



sRGB IEC61966-2.1

This is the Windows default color space, based on the colors that can be displayed on an old-school glass television screen. This is the best color space to use when creating images for the web, for video or for exchange with other computers or applications that do not recognize color space information in image files.

The biggest problem with sRGB is that it excludes some colors that can be captured on film or by digital cameras and/or printed on printers. This causes the working color space to become a potential bottleneck through which the most intense and dramatic colors can have difficulty passing without being altered.

Adobe RGB (1998)

This is a good all-around choice for a slightly wider gamut color space than sRGB. A lot of digital cameras now give you the option of selecting Adobe RGB instead of sRGB. The Adobe RGB color space is a little wider than sRGB, especially when reproducing deep greens.

Better quality monitors now have color gamuts that cover most or all of the Adobe RGB color space. If you have such a monitor, Adobe RGB is a good choice as a working color space since it matches the camera color space, and all the colors can be displayed without clipping.

Most digital cameras let you select sRGB or Adobe RGB as their color space, however this setting as a rule does not affect RAW files, just JPEGs. Most raw converters let you select what color space you want the images to be rendered with, so this setting is mostly ignored. To be guaranteed of the widest color gamut, you should probably select Adobe RGB.

DCI-P3

This color space is a standard from the motion picture industry and is more geared toward video production than photography and printing. Some monitors now cover this color space, and you can use it instead of Adobe RGB. DCI-P3 includes fewer highly saturated greens and cyans, but includes more highly saturated reds.

Chrome 2000 D65 and Chrome 2000 D50

The Chrome 2000 color spaces have a wide color gamut designed to encompass all the colors that can be scanned from color transparency film. This is an alternate color space for scanning, printing, and archiving images that originate on film as it includes nearly all the colors most films can capture, most scanners can detect, and most printers can print. You may see slight color shifts when you use this color space.

SMPTE-C, PAL-SECAM & NTSC (1953)

SMPTE-C is a color space based on the USA video standard while PAL-SECAM is based on the European standard. These older color spaces are good choices for creating images that will be transferred to video. NTSC (1953) is another video-oriented color space, but it is based on obsolete monitor phosphors and should not be used under normal circumstances.

Wide Gamut RGB, Universal RGB and ProPhoto RGB

These are very wide gamut color spaces that aim to encompass all colors in the real world. They are not recommended for normal image editing as much of the gamut is taken up by colors impossible to reproduce on any device. In addition, no monitor can display the extended color gamut so you are editing images without seeing what they look like. Finally, wide-gamut color spaces should only be used with 48-bit color images since you may get posterization with 24-bit color images.

Creating Custom Profiles

While it is becoming increasingly common for scanners, monitors and printers to come with ICC color profiles you can use to create a color managed workflow, there are several reasons why you might want to create and use custom profiles.

- There is no profile available for your scanner, printer or monitor.
- You want to print images using a combination of inks and paper for which you have no profile.
- You suspect your scanner or printer is not conforming accurately to the supplied profile.
- You want to accurately calibrate your monitor.

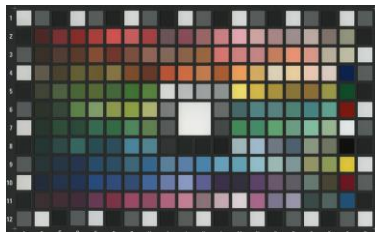
How profiling works

Custom profiles are created by measuring the way your scanner or digital camera, printer or monitor reproduces color. The method for creating profiles depends of the type of device being profiled.

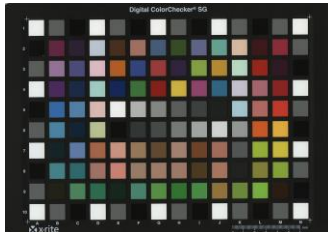
Used with a suitable reference target such as an IT8 transparency or print or a Macbeth ColorChecker, Picture Window can create custom profiles for film scanners, flatbed scanners, or digital cameras. While Picture Window does not let you create custom printer profiles, there are services that can do this for you by having you print a test image and mail it to them.

Profiling a Scanner or Digital Camera

For scanners, digital cameras and other input devices, profiling is done by imaging a test target containing a number of color patches of known properties:



ColorChecker DC



ColorChecker SG



HCT



ColorChecker



IT8



SpyderCheckr 24 and 48

Picture Window's Create Profile transformation can process the target image to produce a custom ICC profile.

Profiling a Printer

For printers, profiling is done by printing a test target containing lots of color patches and then measuring the color of each one with a spectrophotometer.

It is critically important for printer profiling that all adjustments in the printer driver be turned off when printing the test target and when printing subsequent images using the custom profile. A printer profile is only valid assuming that the same inks, paper and driver settings when you print your images as when you printed the test target.

Profiling a Monitor

Profiling a monitor involves correctly setting the brightness, contrast and color controls on the monitor and then measuring the colors of a series of color patches displayed on the screen using a spectrophotometer. In most cases this requires a different instrument than is used to measure printed test targets although there are a few devices that can be used for both purposes.

Embedded Profiles

Embedded profiles are ICC profiles that are included within an image file.

Opening Files

Most image file formats represent colors by three values: their red, green and blue components, usually referred to as RGB color. Raw RGB numbers from a scanner or sent to a printer do not have well defined meanings as they depend on the characteristics of the input or output device. But, when combined with a color profile, RGB data takes on a precise meaning independent of the characteristics of any device, platform or operating system.

The specifications for a number of the standard image file formats including TIFF, BMP V5, PNG, JPEG, have been extended to allow a color profile to be embedded alongside the image data. If present, this embedded color profile provides the information necessary to interpret the RGB values in the file in a device-independent manner.

Picture Window currently supports loading and saving embedded color profiles in TIFF, JPEG, PNG and BMP V5 files only.

Programs that do not recognize the color information embedded in image files will normally just ignore it.

If you use any color space other than sRGB, the program you are exchanging files with must support color management or the images may undergo a color shift when you save them using Picture Window and then load them with the other program. For this reason, sRGB is the safest color space to use if you will be exchanging files with other programs unless you know they support color profiles.

When loading an image with no embedded profile, an assumed color profile is assigned to the image. You can specify the assumed color profile in the Color Management dialog box. The default assumed color profile is sRGB.

When loading a raw file, a camera profile is assigned to the image. You can specify the assumed camera profile in the Color Management dialog box. If you have one, this is where you would specify a custom camera profile.

After loading an image, its color profile is compared to the working color space. If they are different, depending on a Color Management setting, Picture Window will ask you if you want to convert the image to the working color space or leave it in its original color space, convert it without asking, or leave it in its original color space without asking.

The Windows Clipboard

The Windows clipboard optionally supports embedded color profiles, but not every application that uses the clipboard uses this feature. This means you should be careful using the clipboard to transfer color images between applications unless you use the sRGB color space.

Saving Image Files

To export images to programs that support color management, save them as TIFF files and open them in the other application.

To export images to other programs that do not support color management, first use Picture Window's Change Profile transformation to change the image and profile to sRGB and then either use the clipboard or save the image in a file and open it in the other application. Or, you can use the Export command to convert to sRGB and save the file in one step.

Displaying Images on Your Monitor

Sooner or later you will probably get around to viewing images on your monitor.

Monitor Profiles

Ideally, you should have a custom color profile for your monitor.

You can select a profile for your monitor from the Color Management command. You can optionally select proofing in this dialog box, and this will let you preview how image will look when using a particular printer and printer profile (see the section on Proofing below for more details). To disable the use of a monitor profile, select None.

When displaying images, Picture Window converts the RGB data from the color space specified by the color profile associated with the image to the color space specified by the current monitor profile (via the proofing profile, if any).

What Profile to Use

If you are using a hardware monitor calibrator that generates a custom monitor profile for you, use this custom profile as your monitor profile.

If you are not using a monitor calibrator, use your monitor's controls, if possible, to set it to a standard color space such as sRGB or Adobe RGB. Then select sRGB or Adobe RGB as your monitor profile.

Monitor Calibration

To obtain consistent results, accurate monitor calibration is recommended. Monitor calibration ensures that the brightness and white point of your monitor are set correctly, that neutral grays display neutral, that the color primaries are correct, and that the gamma of the monitor is set to the correct curves, resulting in good overall tonal balance. The gamma curve is simply the measured brightness of the screen as a function of the pixel data in an image from 0 to 255.

Here are some important points about monitor calibration:

Warm up and ensure proper viewing conditions

Let your monitor warm up for 15 minutes or so.

Make sure there is as little ambient room light as possible—stray light can throw off your calibration as it obscures shadow detail and causes colors to appear washed out.

Setting your monitor's brightness

Setting the brightness control on your monitor correctly is very important. Most hardware monitor calibrators provide an automatic method for adjusting brightness to a standard value. Typically, the monitor looks best with the brightness turned all the way up as this gives the brightest image with the largest dynamic range. The problem with running your monitor at full brightness is that images that look good on the monitor are likely to print too dark. For this reason, you need to dial back the monitor brightness in most cases.

Calibration

Display adapters incorporate hardware color lookup tables, sometimes called LUTs. Once you load the correct data into the color LUTs, everything you display subsequently in any program you run on your computer will be color corrected.

To achieve the most accurate possible monitor calibration, you need to use a sensor that attaches to your screen and reads the output of the monitor directly. You then use calibration software to display a series of color patches on the screen for the sensor to measure. From these individual color measurements, the calibration software generates a set of lookup table values used to conform your monitor to a specific standard white point and gamma. For this type of calibration to work, the lookup tables must be loaded with the correct values each time your computer starts up, and you must leave your monitor's brightness, contrast and color controls in the same positions they were in at the time of the calibration.

The target monitor gamma

The target monitor gamma value you should calibrate to is 2.2 as this is a good approximation to the response curve of the human eye. The prepress industry standardizes on a gamma value of 1.8 which more closely approximates the characteristics of a printing press.

The target white point

If you are not sure what white point to use, tell the calibration software you want a 6500K or D65 white point. If you want to learn more than you ever wanted to know about white points, read on.

The choice of a target white point can be a little complicated. Because the eye adapts easily to different colors of light, you may not even notice if the white point your monitor is way off until you compare on-screen images to prints made from those images.

To get as accurate as possible a match between your monitor and your printer, you need to match the white point of the monitor to the color temperature of the light under which you will be viewing prints. Typically choosing a D50 or 5000°K white point will give the best match for indoor lighting while D65 or 6500°K works best for outdoor illumination. Color temperature is a scale for measuring the color of light based on black body radiation and is measured in degrees Kelvin (°K). Lower color temperatures are more yellow/orange and higher temperatures more blue. The following list gives a sampling of approximate color temperatures of different light sources:

Match Flame	1,700°K
Candle	1,800-1,950°K
40-Watt Bulb	2,650°K
100-Watt Bulb	2,850°K
500-Watt Bulb	2,950°K
Photo floods	3,200-3,400°K
Quartz Halogen Bulbs	3,250-4,200°K
Moonlight	4,000°K
Electronic Flash	5,500°K
Sunlight at Sunset	2,000°K
Sunlight 1 Hour Before Sunset	3,500°K
Late Afternoon Sunlight	4,300°K
Summer Noon Sunlight	5,400°K
Overcast Sky	6,000°K
Average Summer Daylight	6,500°K
Light Summer Shade	7,100°K
Full Summer Shade	8,000°K
Summer Skylight	8,000-30,000°K

The two most common monitor calibration white points are:

D50 (for all practical purposes identical to 5000°K)

This is the graphic arts and prepress standard for matching standard viewing booths and light boxes. Compared to D65 (see below) a D50 white is noticeably yellow—using this value can make on-screen images look less brilliant, but incandescent and halogen lighting is yellower still. This is the recommended white point to use if you want to get the most accurate match between your monitor and prints viewed using a commercial D50 light booth.

D65 (for all practical purposes identical to 6500°K)

This is the standard value for average daylight, assuming a mix of direct sunlight and indirect blue sky light. On-screen images displayed using this white point are much brighter than at 5000°K, but are significantly more blue than incandescent or halogen lighting. Use this white point if you want your prints to look like the images on your monitor when they are viewed in daylight. If you choose a D65 white point, you should use an Ott-Light or other daylight-corrected viewing light to check prints against your monitor as they will look too yellow under incandescent lighting.

The Relationship between Monitor Profiles and Monitor Calibration

The standard system for using monitor calibration and profiling defines their relationship as follows:

- Monitor calibration brings your monitor into conformance with a specified standard. Since you cannot change the primary colors of the monitor, calibration is limited to adjusting the monitor's brightness, contrast and color controls and adjusting its gamma curves. A typical standard might be gamma 2.2 with a D65 white point.
- The monitor profile tells the color management system what standard the monitor is calibrated to and what are the colors (in device-independent color coordinates) of its red, green and blue primaries. Normally the calibration process embeds color lookup tables within the custom monitor profile it creates.

The system only works correctly when the correct monitor profile and the correct color LUT data are both in effect at the same time. A small program that loads your video card's color LUTs is loaded on system startup.

Proofing

In addition to setting a monitor profile and rendering intent, Picture Window also supports a proofing profile and proofing rendering intent which you set from the Color Management dialog box. Proofing attempts to preview how an image will look when output to a specific printer for which you have a color profile. It works by first transforming your images to the printer color space and then converting a second time to the monitor color space. To disable proofing, set the proofing profile to None.

Proofing is intended to be used to preview how images will look on output devices such as a printing press which have a limited color gamut. It does not seem to work especially well with color inkjet or other color printers that can render certain colors that cannot be displayed on a monitor. You have the option in the Color Management dialog box of setting a Gamut Alarm and Gamut Alarm Color. When the gamut alarm is on and a proofing profile is selected, then colors in your image windows that lie outside the printer color gamut are replaced (for display purposes only) with the gamut alarm color. This lets you see what parts of your image will be subject to color shifts when you print.

When you enable color management and select a proofing profile, Picture Window displays proofing button in the main tool bar.



Proofing Tool Bar

The Proofing Tool Bar is displayed at the top of the screen. It is grayed out unless a proofing profile is currently defined and color management is enabled. You can use it to turn proofing or the gamut alarm on or off. It is strongly recommended that you not edit images routinely with proofing enabled as this gives rise to various visual artifacts—just turn proofing on to do a quick check when you are getting ready to print.

To summarize, there are many ways on-screen color can be altered, all of which need to be carefully controlled and coordinated to get consistent results:

- The settings of your monitor's brightness and color controls.
- The calibration software that generates the color LUT data and custom monitor profile.
- The program that loads the color lookup tables on power up.
- The monitor profile and rendering intent and proofing profile and rendering intent you select in Picture Window's Color Management settings.

Printing

Printer profiles are created by printing and then measuring a test pattern of colored patches. These measurements are then fed into profile creation software which turns them into an ICC printer profile.

For a printer profile to have any meaning whatsoever, the same exact paper, inks and driver settings in use when the original test pattern was printed must all be used again when subsequently printing images using that printer and profile. This means selecting the correct printer profile based on the medium you are printing on, the inks you are using, the resolution you are printing at, and the dithering method you are using, and then making sure that all the driver's color correction and tonal correction settings are set to make no corrections, and that any color management internal to the driver is disabled.

Unfortunately, no specific instructions for making these settings can be given here as the printer drivers and profiles are usually supplied by printer manufacturers or third parties and each one is different. Be very suspicious of any profile you obtain for your printer if it does not come with very specific information about what medium, inks and driver settings to use with it.

Generic printer profiles ignore variations in production runs of papers or inks or other factors that can lead to inconsistent results. For complete control of the color of your prints, or if you need profiles for paper and ink combinations not provided by the printer manufacturer, you may want to consider purchasing the necessary equipment and software to create your own custom profiles. Some of the hardware solutions for custom profile creation also support precise monitor calibration as well (see below for more details).

Picture Window supports color management either within the printer driver or outside the driver.

To perform color management outside the driver, select a profile and rendering intent in the Print dialog box—this is the only way to use custom printer profiles. Since the Windows printer driver model only supports RGB images, CMYK or other non-RGB printer profiles cannot be used outside the printer driver.

To use the printer driver's color management, do not specify a profile in the Print dialog box and use the driver's color management settings (if any).

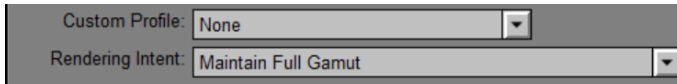
To summarize, there are many factors that can affect printer color, all of which need to be carefully controlled and coordinated to get consistent results:

- The condition of the printer.
- The type of paper and inks you are using.
- The lighting under which you are viewing prints.

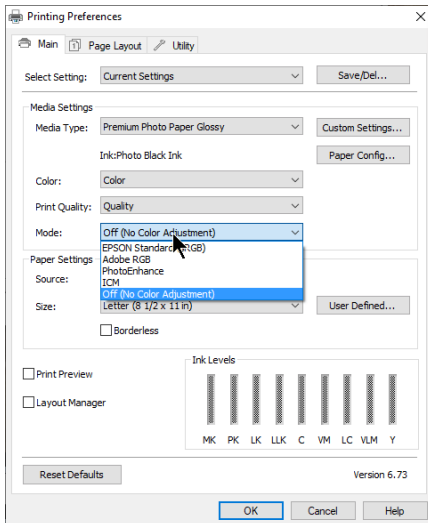
- The software (and instrumentation, if any) that generates the printer profile.
- The printer driver settings.

Printing with color management

There are two ways to print using color management. They differ as to how you set the Custom Profile at the bottom of Picture Window's Print dialog box:



And how you configure the printer driver (Epson P800 used as an example)



Let the printer driver do the work

In this scenario, you set Custom Profile to None and tell the printer driver to handle color management by selecting sRGB, Adobe RGB or ICM, if the image is in sRGB, Adobe RGB or some other color space. This usually works well if you are using inks and media supported by the printer manufacturer.

Use a custom profile

Use this scenario if you are using non-standard media or inks and you have a custom profile for your printer that was created for the inks and media you are using. Set the Custom Profile to the printer profile and tell the printer driver to print with No Color Adjustment.

Either of these two methods can produce good results, with the custom profile giving a little more control. Don't try to mix and match them however or you may get either no color management or color management applied twice.

Limitations of the Windows Driver Model

The Windows driver model provides only a 24-bit RGB data path between the application and the printer. This requires that 48-bit color images be reduced to 24-bit for printing.

Inkjet and most other types of color printers create images by combining inks of four, six and sometimes even more different colors. Depending on their colors, the extra inks can be used to widen the color gamut of the printer, to improve its rendition of highlight detail, or both. Another option starting to appear are quadtone inks—a matched set of four or more neutral gray inks that run from light gray to black. By using the lighter inks to print lighter areas of the image, much finer detail can be reproduced, and smoother tonal gradations can be obtained.

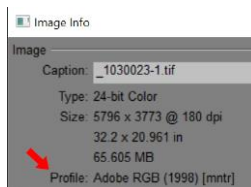
In an ideal world, a color management system would have individual control over the amounts of each individual ink to be able to make the best possible approximation to the original image as specified by a color profile. Indeed, the ICC profile specification allows for working with printers that use four or more inks.

Unfortunately, since Windows driver model only supports sending RGB data to a printer, all decisions about how to use the extra colors must be made in the printer driver unless the printing software bypasses the driver completely.

The Color Space Associated with an Image

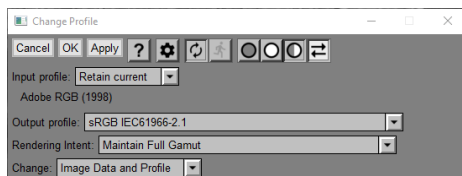
Determining what profile is associated with an image

You can tell what color space is associated with an image by selecting the corresponding window and using the Edit/Image Info command.



Changing Profiles

You can change the color space of an image using the Change Profile transformation. This transformation lets you select a new color space for the image and can convert the image's RGB data from the original color space to a new color space.



To convert an image from one color space to another, set Change to Image Data and Profile Setting. The new profile you specify cannot be a scanner profile since scanner profiles can only be converted from. Also, you cannot select a non-RGB profile such as a CMYK profile for a printing press since Picture Window can only handle RGB image data. CMYK printer profiles can be used as proofing profiles, however.

To simply change the profile associated with an image without changing its pixels, set Change to Profile Setting Only and select the new profile. The new profile can be a scanner profile—this can be useful if you read in a scanned file and want to attach a scanner profile to it after the fact.

Extracting an embedded profile from an image

To extract a profile from an image file you have created or received from someone else, open the file and use the File/Save Profile As... command to save the associated profile as a file. If you store the extracted profile in your system profile folder, you will then be able to use it with other images.

Monitor and Printer Curves

Background - Why Prints Don't Always Match the Screen

Monitor and Printer Curves are a feature of Picture Window Pro created to help you deal with some of the shortcomings of monitor calibration and color management. In an ideal world, printing an image you see on your monitor would produce an exact copy. In reality, even if you calibrate your monitor and use color management and the right monitor and printer profiles, your prints can come out looking dark, dull, and sometimes with a color cast. Some of the reasons for this can be corrected and some are limitations of printing technology. Monitors and printers have very different characteristics and unfortunately translating images from one to the other in a satisfying manner can be complicated.

Dynamic Range

Dynamic range is the ratio between the brightest white and the darkest black a device can produce.

The dynamic range of a good quality print is about 100:1. This means white paper reflects about 100 times as much light as the same paper printed all over with black ink. The dynamic range varies somewhat with the printer, paper and ink, with high quality, glossy prints doing a little better and laser printer output on copy paper doing worse. By comparison, good flat screen monitors have dynamic ranges of 1000:1 or better.

In short, there is a *huge* amount of dynamic range compression going on when you print an image. All the color management system can do is to make sure the transition between full black and full white follows the same curve.

Gamma

The video standard for gamma is 2.2 while the pre-press standard is 1.8. Both of these standards are in common use so the situation can be confusing. Printing a gamma 2.2 image as though it has gamma 1.8 produces a lighter print. Printing a gamma 1.8 image as though it is gamma 2.2 produces a darker print. Be careful in your printer settings to set your printer gamma to match the gamma of your working color space. Often the gamma setting is buried under Advanced Settings or something similar. Color spaces such as sRGB, Adobe RGB, NTSC, etc. are all based on gamma 2.2.

Print Viewing Light

It matters a great deal what light you use to view your prints. Illuminants are characterized by their overall brightness and by their color spectrum. Brightness is measured in units called lux. The color spectrum varies with the way the light is produced. It can be summarized by color temperature or by a color rendering index (CRI), but these are just simplifications. Standard fluorescent lights, for example, have a very uneven spectrum and often render colors poorly, depending on the spectral absorption curves of the dyes or pigments used to make the print.

Color management systems assume you view prints under ideal conditions – typically using a D50 (color temperature 5000°K with a daylight spectrum) light source with a brightness of around 2000 lux. This is very bright. For example, I happen to have a lux meter and used it to measure the typical light levels on my desk which has good north light exposure. It measures around 200 lux, at 10AM in the morning. This goes up to around 700 lux and gets much yellower when I turn on my 150W halogen desk lamp a little over a foot away from the sensor. I also have a commercial viewing booth with a D50 light source and adjustable brightness. Prints generally look pretty good in the viewing booth with the light turned all the way up. However, in the much dimmer light you are likely to encounter in a room where a framed print will be hanging, most prints look muddy and have poor or very little shadow detail.

Monitor Brightness Control

Most monitor calibration software does not tell you how to set the brightness control on your monitor. If you set it as high as it will go, you get the best dynamic range and images with look better on the screen, but this increased dynamic range widens the gap between monitor and printer and makes it harder to get prints to match. If you lower the brightness, on-screen images may look worse but will match prints more closely.

White Point

If monitor white does not match the color of the paper the print is made on as viewed under given lighting conditions, then the print will appear to have a color cast with respect to the monitor. In a typical room, lighting varies wildly depending on the time of day and what mixture of natural and artificial lighting is in use. Fortunately, the visual system is quite good at adapting to different types of lighting, so this kind of mismatch is not usually too obvious.

Normally, you specify the desired monitor white point when you calibrate your monitor, although some monitors also have controls to adjust the relative brightness of the red, green and blue channels as well.

Ambient Light and Reflections

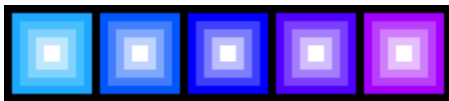
Too much ambient light or light reflecting off the screen will wash out the monitor display. Ideal conditions for viewing a monitor are subdued, neutral room lighting.

Color Gamut Mismatch

The color gamut of a device is simply the range of colors it can reproduce. This is most accurately represented as a 3-dimensional surface in some color space such as Lab but is also sometimes simplified as a 2-dimensional diagram that just considers color of full brightness.

To give an oversimplified generalization, monitors and printers both reproduce unsaturated colors well. Monitors are better at displaying bright, saturated colors while printers are better at dark saturated colors. When a color management system attempts to convert an image in the monitor color space to the printer color space, it needs to de-saturate bright, saturated colors that fall outside the printer gamut. To access some of the printer's best dark, saturated colors, it may also increase the saturation of dark, saturated colors. Gamut mapping remains something of a proprietary art.

There is one quirk of the visual system which can come into play called the Abney Effect. It turns out that as you gradually de-saturate blue light, it starts to look purple as illustrated below in the third and fourth squares. There is also a similar but more subtle effect with red light.



For this reason, sometimes blues that are too bright and saturated for the printer to reproduce are shifted towards purple in the print.

There is not much you can do about the gamut mismatch problem except make several proofs before you print and tweak specific colors using the Selective Color Correction transformation until you get a print you are happy with. Part of what makes printing an art is that there are lots of rich colors you can print that lie outside the color gamut of any monitor. Using these colors effectively is partly a matter of experience and partly trial and error.

Monitor Curves and Printer Curves

Monitor Curves

Monitor Curves are a set of color curves that Picture Window Pro applies to all images displayed on the monitor. Monitor Curves are created via the Color Management dialog box. You can toggle the effect of Monitor Curves on an off with the Monitor Curves button in the main tool bar.



Printer Curves

Printer Curves are a set of color curves that Picture Window Pro applies to images just before they are printed. You can select which printer curve, if any, to use from the **Print** command. As soon as you select a set of printer curves in the **Print** dialog box, the print preview is updated so you can see the effect of the curves.

The Two Basic Strategies to Deal with the "My Prints are too Dark" Problem

There are two different approaches to dealing with the twin problems of dynamic range mismatch and dimmer-than-optimal viewing light.

Darken the Monitor

In this approach, you start by making a test print and then compare it to the version on the screen. If you have a laptop computer, you could move it to the location where the print will be viewed. What makes this tricky is that too much ambient light on the screen affects the display so you need to try to illuminate the print but not the monitor. A good test image will include a full range of tonalities as well as areas of shadow detail. If you don't have a photographic image to use, you can use the step wedge distributed with Picture Window Pro.

Next, create and save a set of monitor curves that darken the image so it looks as much like the print as you can get it. Rather than use monitor curves to darken the image or possibly in addition to using monitor curves, you can also dial back the monitor brightness control if your monitor supports this. If you lower the monitor brightness however, everything will look darker, including output from other programs. You might opt for a combination of these two methods, turning your monitor down a little and using monitor curves to provide the rest of the required darkening. Or, if you have two monitors, you could keep one of them darker than the other and use it to prepare images for printing.

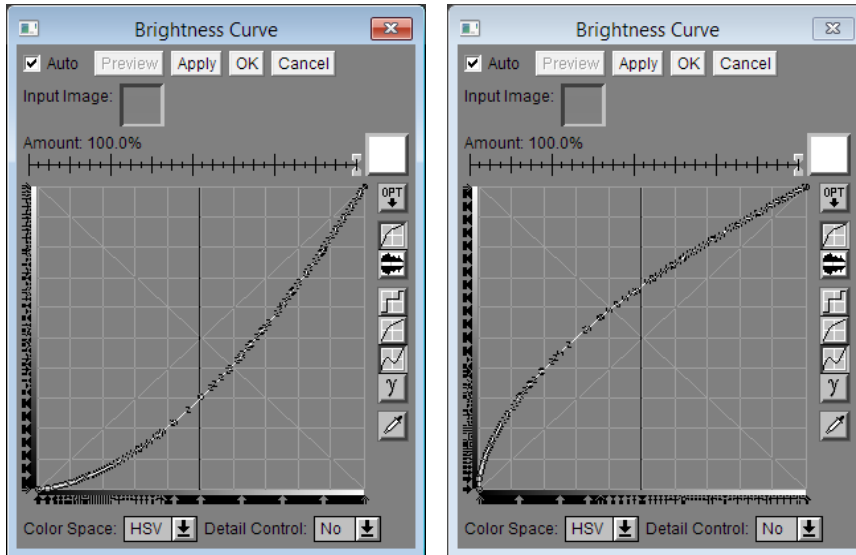
In addition to adjusting the brightness curve of the monitor you can also adjust the color. This feature can be used to correct color casts, even if they are different for different parts of the tonal scale.

Once you have established a match between the monitor and the print you can use these settings to edit images and prepare them for printing being more confident that they will print the way they look on the screen.

One disadvantage of this approach is that you end up with two or more versions of each image you want to print – one optimized for viewing on-screen and one optimized for printing for each set of viewing conditions. This reflects the reality that optimally you need to print differently depending on the viewing conditions. If you are making a limited number of prints and want the best results you can get, this is the way to go.

Lighten the Print

If you don't want to re-edit your images with a darkened the monitor, your other option is to lighten the image just before you print it instead. You do this by selecting the inverse of the monitor curve you created above as a printer curve. An inverse monitor curve is one that undoes the effect of the monitor curve, lightening just as much as the monitor curve darkens. Conveniently, when you save a monitor curve, a printer curve is also automatically saved in the printer curves folder and becomes available as a selection in the Print dialog box. An example of a curve and its inverse is illustrated below:



Curve

Inverse Curve

While this approach lets you keep your monitor bright and work with a single copy of the image, lightening does not increase the dynamic range of the printer, so the print will have less punch than the on-screen image. If you are making lots of prints and don't want to fine tune each image individually, this is the way to go.

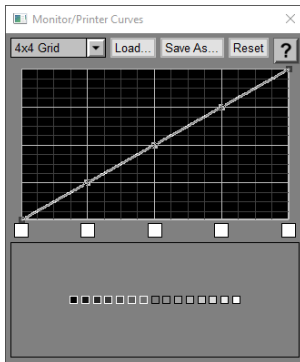
Printing gamma 2.2 images at gamma 1.8 is another way of lightening them, but it is not adjustable so it cannot accommodate different lighting conditions. Photoshop includes a set of grayscale profiles that can be used to lighten prints called Dot Gain 10%, Dot Gain 15%, Dot Gain 20%, Dot Gain 25% and Dot Gain 30% — the 10% profile lightens the least and the 30% profile lightens the most. Since a grayscale profile is just a curve, it is possible to mimic the action of these profiles with monitor and printer curves, and a set of monitor and printer curves that does just this is supplied with Picture Window Pro. If you don't want to go through the process of building monitor curves by hand, you can experiment with of these pre-built curves and use the one that provides about the right amount of print lightening.

One or the Other — Not Both

Make sure you use one approach or the other and don't try to combine them. If you both optimize your images to look good with monitor curves in effect and print using the corresponding inverse monitor curves, you will double-correct and get prints that are too light.

How to Use the Monitor Curves Dialog Box

To create or edit monitor curves, select **File/Monitor and Printer Curves...** from the main menu, at which point Picture Window Pro displays the **Monitor/Printer Curves** dialog box:



The name of the currently loaded monitor curves, if any, is displayed in the caption of the dialog box. An asterisk is displayed after the name if the curves have been modified since they were last loaded or saved.

The controls along the top are:

Grid Size

This setting determines how many control points are placed along the curve. Legal values run from 1x1 to 10x10. The finer the grid, the more precisely you can control the curve, but the more effort it takes to adjust. A setting of 1x1 gives you two control points, one for black and one for white. If you select 2x2 you get three control points with one added in the center for mid-tones. A 4x4 grid has five control points as illustrated above.

Load...

This button lets you load a set of previously saved monitor curves from the Monitor Curves folder. This provides a quick way to select one of a set of commonly used curves.

Save As...

This button lets you save the current monitor curves for later use. Using named monitor curves files lets you create and save multiple monitor curves to deal with each of several different lighting conditions.

When you save monitor curves, at the same time a copy of the inverse monitor curves (obtained by reflecting the curves about the diagonal line connecting the lower left and upper right corners) is saved as a printer curves file. Applying the inverse curves to an image has the opposite effect of the monitor curves. If the monitor curves darken the image, the inverse monitor curves lighten it by the same amount; if the monitor curves add a yellow cast to the image, the inverse monitor curves add an equivalent blue cast (since blue is the complementary color to yellow). To be able to compute inverse monitor curves, the monitor curves must be monotonic; in other words the curve must increase steadily from left to right with no peaks or valleys. If this condition is not met, Picture Window Pro displays an error message.

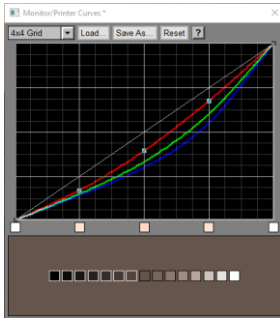
Reset

This button resets the monitor curves. The new curve runs along the diagonal and thus has no effect on the display. Any previous settings are lost.

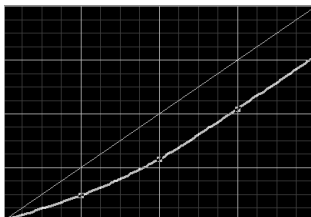
Curve

You adjust the brightness curve by dragging control points (marked as small squares along the curve) up or down until an image on the screen matches a print of the same image viewed under the same illumination it will be subjected to when exhibited. Control points toward the left side adjust shadows while control points toward the right side adjust highlights.

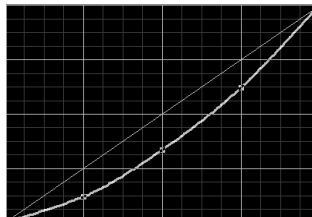
You can also set a color cast at each brightness level by clicking on the small square below the curve. This brings up a color picker you can use to adjust the color for the corresponding control point. As you adjust the color away from a neutral gray, the curve splits into three to show how each color channel is mapped:



If you are using the "darken the monitor" method, the monitor curves should run from full black to somewhat less than full white so as to darken the entire tonal range. If you are using the "lighten the print" method, monitor curves should start at full black and end at full white, otherwise you will further limit the printer's dynamic range. Some sample monitor curves for the two methods are illustrated below:



darken the monitor



lighten the print

Advanced Uses for Printer Curves

Having recently attended a workshop run by Don Messec, I have been experimenting with an alternative printing process. It involves printing an image directly on the surface of a photopolymer plate (reversed left to right), exposing the plate to a UV light source, developing it in a water bath, inking it, and finally printing it on an intaglio press. Because the image printed on the plate is only the first step in the process, it is necessary to compensate for changes in tonality introduced by the remainder of the process. Thus, there was a calibration process where I created and printed test plates and measured the way they reproduced the tone scale. I then needed to apply the inverse of this curve to each image before printing it on a plate, so I created a custom printer curve that does exactly that and placed it in the **Printer Curves** folder. Now I can apply the necessary corrections just by selecting my custom printer curve in the **Print** dialog box.

Should you need to access them yourself, all monitor and printer curves are stored in folders named **Monitor Curves** and **Printer Curves** located in Picture Window Pro's default settings folder. The default settings folder is normally located at **My Documents\Picture Window Pro**.