

What Is Color Profiling?

Why are accurate ICC profiles needed?

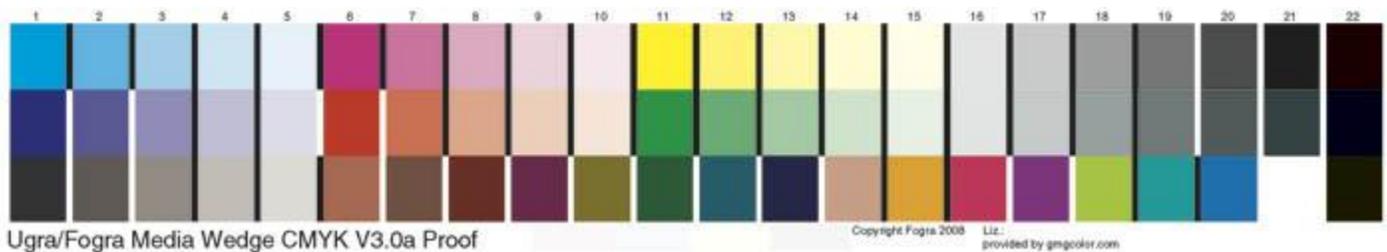
In the chain of capture or *scan > view > edit > proof > reproduce*, there may be restrictions due to equipment capability, i.e. limitations to the range of color and tone which any specific digital device can handle *capture, display or reproduce*, this *range* is known as a device's "effective gamut". Accurate description of device gamut is one very important function of an ICC profile.

No matter how carefully devices such as display screens and printers are manufactured, there are inevitable small variations, even from the same production line. Added to this is the problem of mixing devices from different manufacturers or production lines. So each device might interpret the numbers in an image file differently and if we don't take control each device is likely to produce differing color and tone from that intended.

Ideal working practice requires an automatic way of describing the capabilities of each digital device and a mechanism to compensate for the performance of each. With the right settings, the color management system fulfills this need by using each device's ICC profile and its ability to unequivocally* and accurately describe device capabilities. The color management system can now properly translate digital data between devices using those ICC profiles in order to maintain appearance, within limits of device capability, of course.

Fortunately there are many excellent measuring tools and software which allow us to make accurate ICC profiles for our various devices.

**Unequivocal / Unequivocally are vital terms in color management, basically they mean: leaving no doubt, clear, unambiguous.*



The UGRA FOGRA "Media Wedge", used to check profile accuracy in proofing.

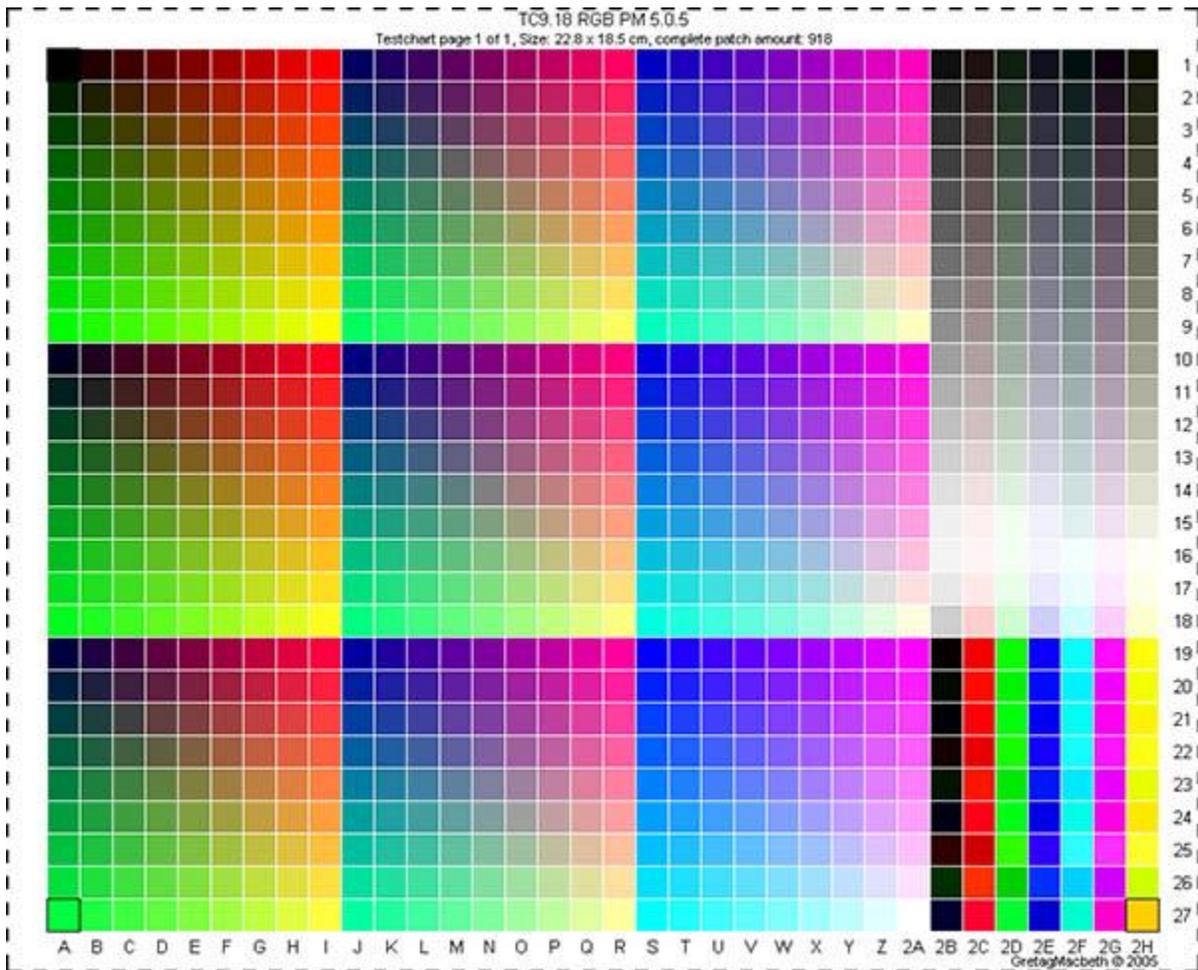
The Media Wedge, above, allows comparison of printed color on a proof directly with a press reference, so can guarantee a match from proof to press.

RGB working spaces are device independent

An RGB working space is a specific type of color space, defined by its ICC profile, it is effectively the hub of many profile based conversions.

Back in the late 1990's, with Photoshop 5, Adobe introduced an invaluable concept to its users, the RGB working space. These "device independent working spaces" are designed to be used for editing and storage or archiving of images. Unlike printer, scanner, camera or display screen profiles, working spaces are not used to describe specific devices.

Output profiles, printing



Output profiles are a type of device color space. Let's start with an inkjet printer; this is profiled by first choosing suitable options from amongst all the available settings in the printer's RGB driver or CMYK RIP software. Options such as resolution and media type can all affect output, so must be optimal.

Next, test prints of a relevant set of color patches are made, using the chosen software settings and using the correct paper and ink.

After drying, accurate measurements of the test prints are made using a high quality spectrophotometer device.

Next, these measurements are analyzed within the profiling software and, in a process of assessing both the measured patch values and the target reference data, the software can produce an accurate device characterization - *an ICC output profile*.

Now, Adobe Photoshop, and other color management capable programs, can use this ICC profile to adjust image data, as it is sent to the printer. This means that we can expect an accurate reproduction of the original image file, within the limits of gamut of the printer and paper chosen.

An ICC printer profile is specific to one certain printer, one type of paper, one inkset and, even, to one print resolution and media setting. If you buy a different make of ink or type of paper, or alter software settings, then the printer will likely behave differently, this inevitably means that the profile we made will no longer describe the printed behavior. So, now, the process of printing using the ICC profile fails to give an accurate printout. A new profile would be needed in order to assess the printer's new behavior. The need for consistency is often called "process control".

Because of the importance of consistency, it is not a good idea to use low cost "compatible" ink cartridges when profiling, because the vital continuity of performance using those inks is very unlikely - due to poor quality control, they often differ, one to the next.

How profiles work - some in depth explanation

There's some science in here in the tech box, and it's not necessary to fully understand this section, but many users find it helpful to have at least a basic knowledge of the workings of ICC profiles, so they cease to become quite so mysterious.

ICC profiles are vital because the RGB and CMYK values in any digital file have no unequivocal* values unless associated with an ICC profile. Once a profile is associated (or "assigned" in Photoshop terminology), then the relationship between the file's numbers and human vision is established. (i.e. RGB or CMYK can now be converted using either of the scientifically defined unequivocal human vision based color spaces XYZ or L*a*b.)

**Unequivocal means: leaving no doubt, clear, unambiguous, a useful term in color management.*

An example: the RGB values R=10, G=100, B=10 have no meaning by themselves other than the color is greenish. That's because the actual colors of the constituents, *Red Green and Blue* are not defined. By associating a color space definition, (i.e. by assigning and embedding an ICC profile) the same RGB values are translated into XYZ or L*a*b giving the values an exact meaning related to human vision. The data can now be passed off to a display screen or to a printer in a process that uses those exact color definitions - terminating in a conversion to optimize the data for the receiving device.

Having a set of RGB or CMYK values associated with a defined color space (as in "with an embedded ICC profile") allows for the exact reproduction of the color.

About L*a*b* and XYZ color spaces

You'll hear mention of these color spaces and their use as way of defining color, when you're getting into understanding ICC profiles. So, what are they? Both L*a*b* and CIE XYZ color spaces are designed to encompass human vision. These color spaces define color using a full scale, based upon how humans see color, so that a particular set of values always means the same color. As you learned above, RGB and CMYK don't work like that.

CIE L*a*b* (normally named just L*a*b*) color space is based on the CIE 1931 XYZ color space, formulated to contain the whole range of colors and tones visible to the human eye and referenced by numbers that provide unequivocal color meaning. The CIE XYZ color space was derived from a series of experiments done in the late 1920s; experimental results were combined into a specification from which the CIE XYZ color space was derived.

In summary, XYZ and L*a*b* numbers are unequivocal. Unlike numbers in the RGB or CMYK color models, L*a*b* and XYZ numbers have an actual meaning.

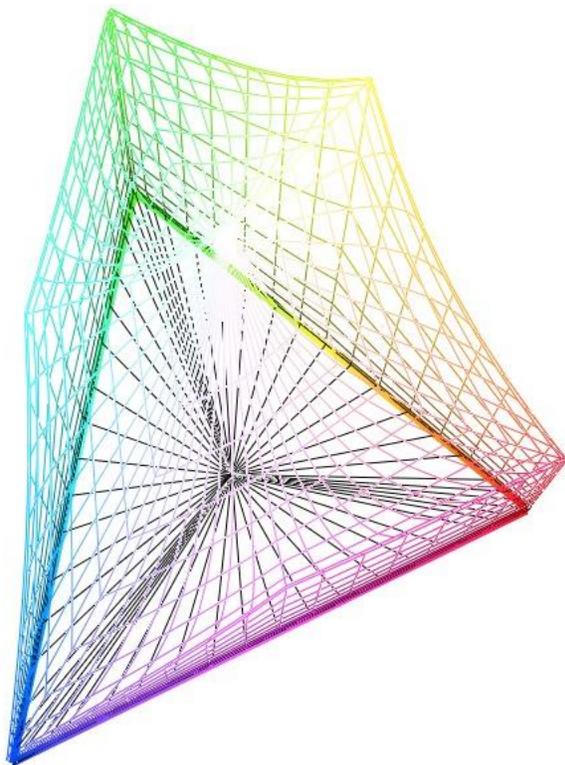
F.Y.I.

L*a*b*: L* = lightness axis, a = Green to magenta axis, b = Blue to Yellow axis.

XYZ: Y is luminance. Z and X are related to human cone response curves.

There are lots of papers online for those who'd like to delve further but that's certainly not needed in a quest to better understand how ICC profiles work in practice. Just appreciate that XYZ and L*a*b* define color properly, unequivocally.

ICC profiles



Any ICC profile contains one or more tables to allow calculation between “device color space” ICC and XYZ or L*a*b color space, or the inverse.

*Even a working color space like AdobeRGB(1998).icc (3D pic. right) is treated as a "device color space" in this scenario. Some ICC profiles do contain quite a few tables to allow for conversion using different rendering intents, but, basically, all those tables do is to provide for variants on the above calculations. L*a*b* or XYZ are used in ICC profiles as the Profile Conversion Space or P.C.S. - because they are unequivocal, each numerical value in either XYZ or L*a*b defines a single color relative to human vision.*

Basically, the following describes the way the profiles are used in an RGB or CMYK print conversion

A: “document” (perhaps an image) RGB or CMYK converts to XYZ or L*a*b

- then -

B: XYZ or L*a*b converts to printer RGB or CMYK.

Liken this to translating a word from French to German without access to a French to German dictionary.

If you had a French to English dictionary and an English to German one you could do it in two steps:

A: Translate from French to English

- and -

B: Translate from English to German.

In this example English is acting as the “conversion space”, the P.C.S.

When a conversion between two color spaces takes place we are normally offered a choice of rendering Intent. For output conversions all the intents, Perceptual, Relative Colorimetric, Absolute Colorimetric and Saturation are all available within the process and will affect the result. However, when converting from an input color space to working space, although Photoshop offers the options above, all that's actually available is a form of Colorimetric rendering. There are some important implications to this because image data can be clipped during the conversion process which may happen unnoticed in the background. Issues arise especially if the working space is not large enough to contain all the image data which happens all too often. Disappointment with image quality, especially in detail in dark, light or saturated areas may result and, although this may be thought an inevitable part of the process, there are sophisticated ways of controlling it. Taking control of this, by careful working space selection and properly managing the process, is key.

Making a printer profile, in detail

In an attempt to make a description of the ICC print profiling process easy to comprehend, many writers, myself included, have alluded to a process of comparison between printed results and the actual desired appearance of the patch file. That's not entirely wrong in spirit, but, technically, calculating an ICC profile is NOT a process of comparison of printed (output) to patch values. This is because the patches actually have no "ideal" appearance (i.e. no L*a*b* values - please read on to understand that better). The ICC profile *does have* an ability to adapt color data (perhaps in an image) before printing and, thus, the result is printed material that compares well to desired or “correct” appearance. SO, good

comparison *is* the end result, but comparison's not included in the actual process of making the ICC profile.

In practice, $L^*a^*b^*$ measurements of the printed patches are analyzed within the profiling software and, in a process of assessing how the measured patches (measured in $L^*a^*b^*$) relate to the target reference data (expressed as RGB or CMYK), the profiling software can produce an accurate *device characterization* - a table for calculation between $L^*a^*b^*$ and RGB or CMYK, which is used in the ICC output profile.

You read earlier that RGB and CMYK values are ambiguous, because the primaries are not defined, well, here in the printer profile; the ambiguous file values of the target are made unequivocal by the table calculating between printed output and target values.

The ICC profiling process involves a few steps, which are worth explaining

1: set-up printer and print a file with RGB or CMYK patches



It's vitally important at this stage that either the printer control software (i.e. driver or RIP) settings or press adjustments (CTP tone curves, ink weights etc.) are chosen properly; often this ideal machine state is reached as a result of a process of step-by-step testing of various options. This method optimizes the process. Thereafter, those same settings must be used whenever the profile is to be used. Consistency is king, machine behavior must be invariable.

So, what are we printing in this patch file? The RGB or CMYK patch data in the image file is allowed no embedded ICC profile, so it has no associated $L^*a^*b^*$ or XYZ "visual" values and nothing to inform a conversion to $L^*a^*b^*$ or XYZ, thus, there is no way that its values can actually be related to a visual color meaning. The file data has no unequivocal appearance, the numbers are ambiguous.

How can we see patches on screen then? On screen display of patch files is, as default, made using a "guess" as to document color space.

We must not assign an ICC profile to patches in practice, because it could invalidate the printing process. We need raw CMYK or RGB patch data printed.

But, if an ICC profile were assigned** to the file with the patches, then the color management process would provide L*a*b* or XYZ values for each patch and, this information, passed through the monitor profile, can provide what is shown on screen with a visual appearance. So we have now given those patches "unequivocal" values - but this is only one possible appearance, one interpretation for the values of those RGB or CMYK patches, because if a different ICC profile was assigned to the patch file, then the visual appearance would change, (this happens because the calculated L*a*b* or XYZ values would change).

**In Photoshop and similar applications, when an image without an ICC profile is displayed, the L*a*b* or XYZ data normally provided by a profile is missing. So, it's not possible to send the data through the screen profile to the screen - therefore, to allow display, Photoshop assumes (i.e. temporarily assigns, for viewing only) the default working color space profile – just so the file can be shown on screen. This doesn't affect the printing process, but it does explain why the file appears to have a set appearance on screen.

2: measure the printed target



The printed patch set is measured using an accurate spectrophotometer.

As you read above, after printing and reading the target no *comparison* to anticipated results is actually made, because there is no anticipated result for the printed patches.

So, what does actually happen?

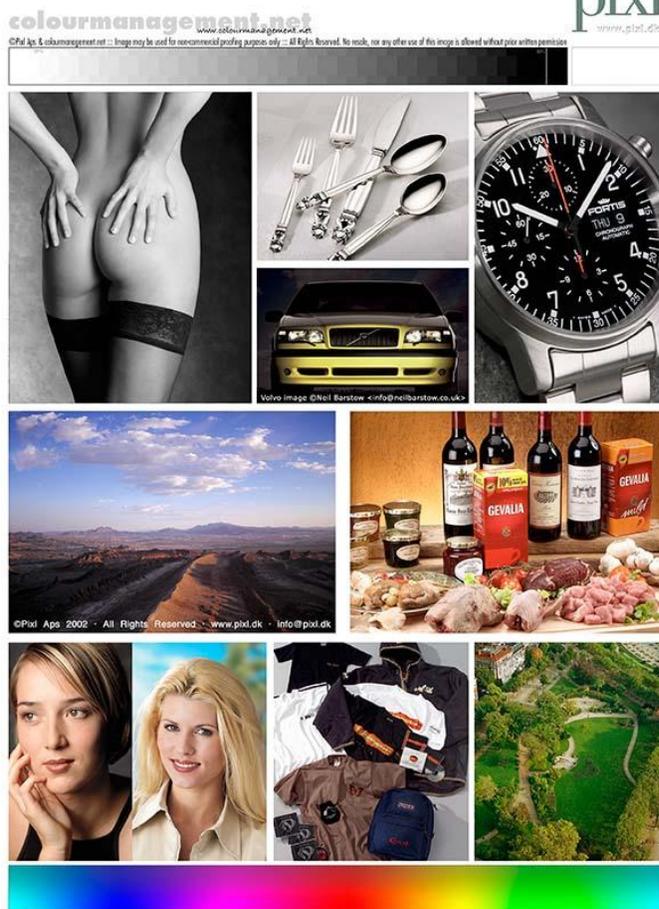
3: calculate the profile

Colorimetric values in XYZ or L*a*b* result from the measurement of the printed target. Reference data for the patch set containing the original RGB or CMYK values for each patch is used, in conjunction with those measured values, to calculate and build the “device values to XYZ or L*a*b*” table which is part of the ICC profile, *this is called the A2B transformation table*. This table simply describes the printer to

software, so that the system "knows": "What happens if I send particular RGB or CMYK numbers to printer - what *actual color* (what visual appearance) will result".

This table A2B is not actually the part of the output profile used when converting a file to print it, it's an "inversion" of that table - into an XYZ or L*a*b* to device transformation table, *called the B2A*, that provides the information needed for this important transformation. What the system can learn from this table is "I have read the profile of a pixel in the image, so now I have an XYZ or L*a*b* value to print; what RGB or CMYK numbers do I need to send to the printer to get that appearance?"

Pixl / colourmanagement.net testimage



Using the printer profile, printing

When selected in an imaging application like Photoshop, the printer's ICC profile provides a prediction, which is used, along with the document profile, to work out how to alter each of the document file's pixel values to get a print that looks like it should. That is, it should closely match the source image shown on a calibrated and profiled display screen, or another print from a profiled workflow.

It works like this, *document RGB or CMYK is converted to XYZ and then XYZ is converted to device RGB or CMYK.*

Using the printer profile, softproofing

Good printer profiles can be used in on-screen softproofing in order to predict printed output on a well set up monitor screen. This useful *output preview* process is available in Photoshop and some other imaging applications; softproofing provides a screen preview, simulating the output of a printer, which can be viewed during image optimization. Of course, accuracy in softproofing relies on having a decent quality, well calibrated and profiled, Display System and a good accurate output (printer) profile. Without going too deep, the process involves the original file's values passing "through" the printer profile en-route to the display profile.

document RGB to XYZ or L*a*b*-and- XYZ or L*a*b* is converted to printer RGB (or CMYK)
printer RGB (or CMYK) to XYZ or L*a*b*-and- XYZ or L*a*b* is converted to display RGB

Using a camera or scanner ("input") profile



The ICC input profile is used to compensate for consistent issues in the capture or scanning process. The relevant ICC profile is assigned to the image when opening any original capture or scan. In many software applications, the profile can be assigned and embedded automatically. Assigning the ICC profile to an incoming image provides for accurate appearance on screen through a transformation using the input profile and display profile - and, often, also the chosen working color space profile.

In initial display on screen, once the device ICC profile is assigned, each pixel in the RGB image file is
A: transformed to XYZ or L*a*b* - and then -
B: XYZ or L*a*b* is transformed to monitor space RGB ICC.

In most cases device RGB is converted to a working space first, so

A: device RGB to XYZ or L*a*b* - and -
B: XYZ or L*a*b* is converted to working space RGB ICC.
- then -
C: working space RGB ICC is converted to XYZ or L*a*b*- and -
D: XYZ or L*a*b* is converted to monitor space RGB ICC (or even printer color space ICC if printing at this stage).

Much of this is dealt with automatically in a well set-up system.

Profiles for free?

Unfortunately, however well intentioned they may be, ICC profiles supplied with products or found around the internet which might claim to accurately represent a particular device can often be quite poor. Since each individual device may differ, these “canned” or generic profiles are sometimes only useful as a starting point. In some instances the provider even fails to provide instructions on device settings for use with their profile.

Making a profile from one printer and attempting to use that same profile on a different printer, even if it's the identical printer model using identical paper and inks, is unlikely to provide identical or accurate results.

Success with color management relies on good device characterization, provided by ICC profiles and on consistency in devices and working methods.