

Creating Monitor and Printer Profiles – A Detailed “How To” Guide

In the “Introduction to Color Management”, I discussed some elemental aspects of color theory, human vision and how and why Color Management works. We only touched the surface of this deep and highly complex subject, but hopefully it laid a solid enough foundation for the average photographer, designer or printer to benefit and delve into to the details of how to build profiles. You don't *need* to read the first article in order to build and use color profiles, but it certainly helps to understand the basics.

This article includes step by step details of how I create custom profiles for my devices, along with additional theory, when necessary or helpful. It will also discuss how to use these profiles to print images from Photoshop to a color inkjet printer.

I will spend the bulk of my time discussing monitor and inkjet printer profiles, though I will also touch on scanners, printing presses, lightjets and other devices. I will also touch briefly on the use of RIPs (raster image processors). This paper is not meant to be an exhaustive treatise on color management, but should describe more than enough to walk through the process.

Best Bang for the Buck

If you are serious about and need control over color, there is no doubt about it....start by profiling your monitor. There are a few good reasons.

First, most people edit images and documents visually, at least in part. So, if your monitor's colors are inaccurate, you will be editing the 'numbers' in your digital file based on bogus input. You may be adding more yellow when the file is actually too yellow already, but your display says it is too blue. Of course, when you print, your output will be overly yellow.

Second, monitor profiling is very inexpensive, especially when you consider all the investment most people have in digital cameras, lenses, scanners, inkjet printers, computers, etc. A good monitor profiling package (colorimeter and software) can be bought for only a few hundred dollars, and you will use it over and over again, and also on multiple workstations.

Third, monitors drift over time. CRTs, which are mostly out of use with the rise of flat screen LCD monitors, can drift significantly over a few days or weeks. LCDs tend to be more stable and are usually fairly accurate over a few weeks to a month. It is usually a good idea to calibrate and profile your monitor every few weeks or at least monthly.

Fourth, not everyone's working or viewing environment is the same, and this necessitates some adjustments.

Fifth, monitor calibration and profiling software and hardware provide accurate repeatability that the human eye simply cannot duplicate. The eye is easily fooled, but a calibration instrument is not.

It bears repeating....if you are serious about color, buy a decent monitor calibration and profiling package.

While certainly not optimal, 'canned' printer profiles supplied by printer OEMs *are* improving, so they are often fairly close and give pleasing color, at least with that vendor's proprietary papers. Custom profiles offer a much better solution, but more on that later.

Another option is to have a professional come in on a regular basis to recalibrate and profile your monitors, but this is clearly more expensive than purchasing a monitor profiling package (usually about \$200 or so). The same cannot be said for

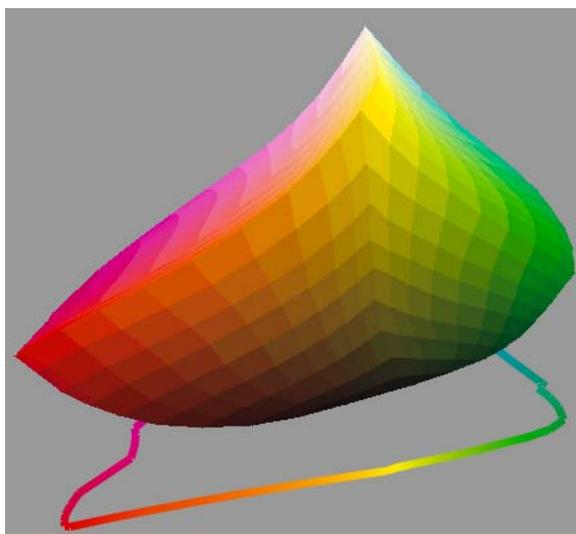
printer profiling, since a spectrophotometer and good printer profiling software is expensive (in the thousands of dollars).

For reasons that will become clear later on, I will now shift gears and discuss the creation of custom printer profiles first.

Custom Printer Profile Introduction

As discussed in my article, Introduction to Color Management, an accurate profile describes a device's gamut (or boundaries) in addition to how to generate a specific color that falls within that gamut. A profile is a "map" of the territory as well as a translation guide to get you where you want to go, in this case, accurate, predictable color.

Below is a 3D gamut plot (created using ColorThink Pro software) showing the volume of colors that can be reproduced on Ilford Gold Fiber Silk paper using my Canon iPF6100 inkjet printer. The solid colored line below is a 2D projection, as is less useful than its 3D counterpart. All the colors that fit into the 3D solid are considered 'in-gamut' colors. Any colors in my file that fall outside the solid are 'out of gamut', ie, they can not be reproduced using this printer/paper/ink combination.



3D gamut plot of Ilford Gold Fiber Silk paper on a Canon iPF6100 12-color inkjet printer

If you have an old or inaccurate map, you may not always end up where you want to go, or you

may find that a road is closed. I have had this particular experience with the GPS system in my car, which never seems to be 'up to date'. In the same way, we need a 'map' for your printer to help us define the printer's boundaries. This map is called an *ICC profile*.

In a nutshell, to create a profile, we print a profiling target consisting of hundreds or usually thousands of predefined colors, read those colors with a color spectrophotometer, compare the printed colors to the desired colors as defined in the original file, then build a profile. The profile establishes the printer's boundaries (color gamut) and tables for translation. But, it's not that simple and there are a few caveats.

1. Not all papers are created equal.

If you have ever printed the same image on cheap copier paper and then on high quality photo paper, you know what a tremendous difference there is between the two. Copy paper looks washed out, lacks saturation and dynamic range, has weak blacks (ie, poor Dmax, or poor maximum density), whereas the high quality photo paper is stronger on all counts. *All* papers react differently to ink, but each paper has an optimum amount and type of ink that it requires to bring out its best in terms of color gamut, smoothness, separation of tones and Dmax.

Simply printing a profiling target *does not guarantee a good profile*. Remember, a profile is a map that describes the territory. If we print a profiling target with lousy settings, we will get a weak looking target. When we read that weak target with our spectrophotometer, the software will think the paper has a more limited color gamut than it really does. This weak target, in essence, sets the final boundaries in our profile, and it sets them to be too narrow and limiting.

So, we need to establish the very best printer driver or RIP (Raster Image Processor) settings BEFORE printing our target, so we get the absolute best target possible. When we read a great target with the spectrophotometer, we invariably get a great profile with wider gamut, better Dmax (deeper blacks) and excellent tonal separation (so shadows and highlights don't bunch up together and get lost).

2. Driver/RIP settings are crucial to a good profile. I will discuss the process using a standard RGB printer driver here and get into RIPs later. Most printer manufacturers ship their printers with drivers that convert RGB pixel data into ink dots. CMYK is the basis on which most continuous tone images are created, but CMYK is a bit of a misnomer here, since today's inkjet printers generally use additional inks. Still, the core of the subtractive printing process is CMYK. Epson printers typically use 8 inks (C,c,M,m,Y,MK,LK,LLK) on matte papers, with a different black for Photo Papers. The capital letters refer to standard inks, and the lowercase letters usually refer to a lighter variant, so 'C' would represent Cyan, and 'c' would represent light cyan. Many Canon and HP printers use 11 inks at one time, such as (C,c,M,m,Y,MK,LK,LLK,R,G,B) for matte papers. As with Epson printers, a separate and different black is used for photo paper. Each black ink formulation is designed to produce superior results on the two different types of media. The driver's job is to convert RGB file data into ink dots, but that is a tremendous oversimplification. For our purposes here, the driver also controls the dot pattern(s), dot sizes, the amount of ink laid down (ink limits), gray balance, separation of tones (ie, linearization), the printing quality and speed, etc.

The ink limits, linearization, ink blends and other parameters are determined by the OEM for their own branded media and are hard coded into the media settings inside the driver. So, if using an Epson printer, and printing on Epson Velvet Fine Art paper, you would generally be well served by selecting the Epson Velvet Fine Art media setting in their driver, since Epson presumably spent a lot of time trying to get the amount and balance of inks correct for *their* paper. They want to sell a lot of paper, so it is in their interest to make sure their settings are very good, and they usually are for *their own papers*. But, with new or unlisted papers, or worse yet, media manufactured by an independent paper supplier, testing is often required to find the best available media setting in the driver. I'll get into this when describing the actual step by step instructions.

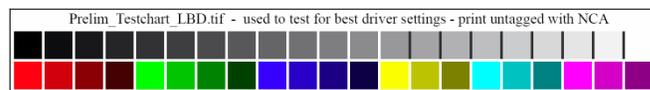
3. It follows logically that each paper needs its own profile. More precisely, *each printer/ink/paper combination needs its own custom profile.*

We already know that papers can vary, sometimes dramatically, in how they respond to ink. Likewise, not all inks (Epson, Canon, HP, or 3rd party inks) are the same, and the paper responds differently to each manufacturer's inks. In addition, not all printers are the same, even when they are the same make and model. Firing picoliters of ink is an exacting job and there are differences from one Epson 7880 to the next, one Canon iPF6100 to the next, etc. So, for *your* printer and *your* ink, you need a profile for each and every paper you print on for optimum, predictable results.

Printer Profiling – Step by Step

1. Determining the best driver setting

In the comfort of my own home, I have an advantage. I own a color spectrophotometer which I can use to measure results from a preliminary test target BEFORE printing my profiling target. You will have to do this visually. Below is the target that I use to help me perform this function.



The target is about 7.5" wide and 1" high, so I can print it up to 10 times on a single sheet of letter sized paper, *but each time using different driver settings*. If I were profiling Crane Museo Max fine art paper on my Canon iPF6100 printer, I would print this same exact target using the most likely '*media choices*' available in the Canon driver (the media choices contain the ink limits, linearization and ink blending algorithms). Make sure the media settings you choose utilize the matte black ink, which is appropriate for fine art matte type papers.

The above file contains 21 steps of gray and different shades of red, green, blue, cyan, magenta and yellow. When opening the file in

Photoshop, **be sure to leave it ‘untagged’** (ie, do NOT color manage). This makes sure there is no profile attached to the target (ie, no embedded source profile).

When printing the target, we make sure that **both** Photoshop and the printer driver have all color management controls set to “OFF”. Since we have no tag assigned to the file in Photoshop, and print it without ANY profiles, we are sending **RAW RGB DATA** to the printer driver. This is critically important when printing any targets for profiling.

Normally, speed is not an issue in my work, so I almost always choose the highest quality, lowest speed settings for printing. (this usually gives the best quality output, but not always. I have tested for this too and depending on the printer and paper, I sometimes see some surprises)

After printing each test strip on my sheet of paper, I write down the driver and media settings I used so I don’t make any mistakes.

2. Reading the Test Strips

I then let my page full of test strips dry for an hour or more, or hasten the process with a hair dryer, or about 15 seconds in a microwave oven. Then, it is time to figure out which driver setting is best.

I usually start by reading the darkest 4 or 5 black patches of the test strip with my spectrophotometer. Typically, I want to find the driver setting that gives me the blackest black (1st black patch, which is set to RGB=0), but I also want to make sure I can read tonal differences between each step. If the first 2 or 3 steps read the same density, it means we probably have used too much ink, and that shadow details in our final profile are bound to be blocked up (ie, poor shadow separation).

Once I have narrowed my list down to the 2 or 3 best driver settings based on Dmax and separation of shadow tones, I will look at the colored patches, especially the brightest, most saturated red, green, blue, cyan, magenta and yellow. Some media settings may provide a bit

more Dmax (best black) but may show a little less color saturation. Others might have a bit more saturation, but skimp slightly on Dmax. Usually, there is one setting that is best overall, though perhaps not in every single category. That setting will usually be my final choice.

I don’t rely totally on my spectrophotometer, though it is very helpful. I also inspect my best candidates closely under a loupe, looking for any evidence of over inking, such as pooling of ink, mottling (blotchiness), bleeding along the edges, fogginess, etc. Settings that suggest I have exceeded the best ink limit will be rejected.

If you don’t own a spectrophotometer, you have a few choices, since sending targets back and forth is ludicrous. First, you find someone you trust who has the same printer and uses the same paper, and find out what driver settings they are using. If they are as meticulous as I am, you will generally end up with an excellent media setting.

Second, you can assess things visually, which will help you weed out the obvious losers, but it will be harder to separate the good from the great. Close inspection under a bright light with a loupe can help. If you see white flecks in your solid black patch, you probably need more ink, a slower print speed, or perhaps should consider unidirectional printing instead of bidirectional.

Third, you can scan the page with a “good” scanner and open the file in Photoshop to compare results. Scanners vary tremendously, and they are not as accurate as spectrophotometers, especially in the dark registers, but they *can* often provide some relative comparisons that will help you identify better media settings.

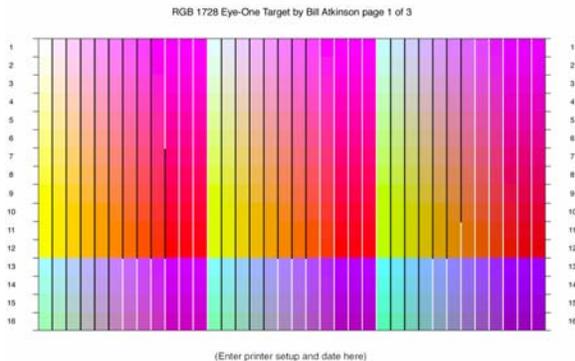
Whichever method is used, you select the best driver settings possible and use those exact settings to print your profiling target. I also recommend that you save those custom settings in your driver so you never forget them.

Determining the best driver and media setting is actually the most important and difficult part to building great custom printer profiles.

3. Printing the Profiling Target

I use a 1728 patch RGB profiling target designed to be read in X-Rite ColorPort software, and use an Eye One Pro Spectrophotometer when building custom inkjet profiles. This target allows me to build profiles with both ProfileMaker and Monaco Profiler software. (Profiling Targets can be downloaded from my website). If you want to print a single target all at once, you will need to print on 17x22 inch paper (or roll stock). If you prefer to print on smaller paper, you will need four letter or A4 sheets, or two 11X17 sheets. (Letter sized sheets are best for mailing). These targets subdivide the same exact patches onto multiple sheets and give identical results.

Below is an example showing part of a 1728 patch profiling target for use with 8.5x11 paper. It contains rows and columns of patches. Each color is separated by white or black stripe, which tells the spectrophotometer that a new color is ready to be read. When printing on letter sized paper, you will need to print all four targets. Those who print on 11X17 or 13x19 paper will need to print two targets. On 17x22 paper or roll stock, a single target can be printed.



You will open your profiling target(s) in Photoshop **“untagged”** (do not color manage) as you did with the preliminary target. When printing from Photoshop, you will want to be sure that color management is set to **“OFF”**. Your printer driver will be set to use the EXACT SAME SETTINGS used to print your best preliminary target, ie media setting, dpi, quality, speed, **with color management turned off.**

Again, this makes sure that raw RGB data is fed to the driver and not converted or adjusted by a profile. Your choice of media settings, quality, speed, dpi, etc., will influence the final target, but that was the purpose of the previous test – to get a good target in the first place.

Before printing, make sure your printer has a perfectly clear nozzle check, that paper is clean and dusted off, has no oily finger prints, etc. Then print your target(s). This time, **let them air dry overnight instead of using a hair dryer.** The most important thing you ever print is a profiling target, because it will affect every single print you make thereafter when using that profile, so it is worth doing right the first time.

4. Mailing Your Target

Before packaging your target(s), be sure to write on borders of your targets the settings you used to print the target, the type of paper, media settings, printer model and your name and email address. Then, I recommend you place a clean sheet of paper between each printed sheet (or a cover sheet over the target, if rolled). You want it to arrive in pristine fashion. Then package and mail it, along with a check, to the address listed on my website.

5. What I do When I Receive Your Targets

When I receive your target(s), I will email you that it arrived (be sure to include your email address). I will inspect the target for damage and quality. I will dust it off with a drafter’s brush and blow it off with canned air to make sure it is clean. Then I will lay it on a white backing surface and read it with my Eye One Pro Spectrophotometer. I currently use both ProfileMaker5 and/or Monaco Profiler for building profiles. Once I have read all 1728 patches, I will save the data in my files.

Then I instruct ProfileMaker to build me two profiles, using two different algorithms. I create a profile with the **“Colorful”** algorithm, and one with the **“Chroma Plus”** algorithm. These are just different recipes for handling ‘out of gamut colors’ and give you options for handling your images. (More on this in the section on How to

use your profiles). I also build profiles with Monaco Profiler.

I will save the profiles with distinct names, so you know the printer, paper and algorithm. For example, if your name is Bill Williams, you are using an Epson 7880, and you are profiling Crane Museo Max paper, your profiles will be named as follows (unless you provide different instructions):

- BW-7880-MuseoMax-Colorful.ICC
- BW-7880-MuseoMax-Ch+.ICC
- BW-7880-MuseoMax-MP.ICC

Once profiles are complete, I will inspect them in a software program called ColorThink Pro, which allows me to see how smooth the profile is, the Dmax, the white point of the paper, the color gamut, etc, and compare it to profiles made on similar papers. A well made profile is smooth, doesn't have any reversals, has good solid blacks, good transitions and good color gamut. Almost invariably, a well printed target using excellent settings will give you a good profile. A poor printed target, a damaged target, inferior paper, improper driver settings, settled or expired inks, or other factors can result in a sub par profile. But this will be evident to me in ColorThink.

I will email you your profile(s), and refer you back to this document for how to use them. I will also tell you what I think of your profiles, including the Dmax, color gamut, etc. I will also tell you the color of your "white" paper.

Monitor Profiling Instructions and Recommendations

.....which brings me full circle. Monitor profiling is one of those areas that is open to dispute and disagreement, and it seems everyone has their opinion. So, I will express mine, how I came to my conclusions, and also why I decided to come back to monitors *after* discussing printer profiles.

With printer profiles, once your target is printed and dried, your color is set. Paper white doesn't change (unless you use inferior paper and it

yellows), blacks remain the same (unless you used expired pigments or decided to use less stable dye inks), color gamut is set, etc. The spectrophotometer collects the data, using its own internal, calibrated, industry standard light source. There really are no other external variables to contend with. The data is then feed into software to generate a profile. The spectro simply records spectral data for paper white, black, red, green, lavender, baby blue and the remaining color patches. There aren't that many user options that can trash the profile.

Nothing is perfect in this world, and certainly not printer profiles, but I usually trust a good custom printer profile more than I do a monitor profile, since so little is dependent on human input.

Not so with monitors, however. You can adjust your monitor to give you a warm white, blue white or anything in between. In fact, you can make it very bright, very dim or somewhere in the middle. You can adjust the gamma, or use L* coordinates if your software supports it. Some monitor hardware and software lets you adjust the monitor black point so it is darker or lighter. So, profiling a monitor involves a lot of choices and possibilities that are not possible with a printed target. So, which settings should you use? The definite and precise answer is, "It depends."

If you read the precursor to this article, you know how complex and involved color perception is. For our purposes, getting a good monitor to print match, we will narrow it down to a handful of components ~ final viewing environment, ambient lighting in your office (where you do your editing), and your viewing lights or viewing booth. All of these, including the 'sweet spot' for your monitor, affect your results and could affect your choice of settings for monitor calibration, but in my considered opinion, only within a fairly narrow range. I'll explain.

My deepest desire when I first got into color management, was to be able to calibrate my monitor to 6500K white, 2.2 gamma, and have a nice bright monitor. Why? Well, those are the

standards set for both sRGB and Adobe RGB, plus the worldwide web also uses sRGB as a standard (though it is largely un-color managed). It made sense to use 6500K if possible. That would make life SO easy, wouldn't it?

Well, the only problem was it didn't work, at least not for me, my environment, lighting, monitor, etc. No matter what I did, my prints always looked MUCH yellower than my monitor. This color cast was most noticeable in light grays and whites, which human vision is very sensitive to. I tried different viewing lights and finally bought industry standard viewing lights. Still too yellow. I changed ambient lighting levels and worked in a cave. Nope, still too yellow. I even painted my office neutral gray and worked in a black shirt to avoid any possible spillover of color or color perception.

What I discovered through hundreds of hours of testing and experimentation was that my prints weren't too yellow, my monitor was TOO BLUE. Because it was too blue, I was adding more yellow to my file during editing, and this reliably showed up in my prints. So, I spent years experimenting with different monitor settings, and I ALWAYS came back to the same ones. I'll tell you in a minute, but I want you to understand how anal and determined I was.

I measured 20 or 30 different printing papers, and they all measured between 4700K (warm) to about 5250K (bright white). Then I read gray step wedges on my monitor using my spectrophotometer in transmissive mode, with my monitor calibrated to dozens of different color temperatures. My eyeballs confirmed what my spectrophotometer was telling me. They told me that anywhere between 5000K and 5500K was just about right, and neutral. Personally, I have settled on 5200K, which I find to be the perfect monitor white temperature for a good monitor to print match, at least on **my** monitors and **my** system. I don't think it is a coincidence that paper white measured on a broad range of papers comes very close to my monitor white, all the esoteric arguments notwithstanding.

I also happen to believe that most monitors have a 'sweet spot', or a range within which they perform well. If you stray too far from a monitor's comfort zone, you will see a rapid falloff in performance. I'll touch on this again later.

Now, to gamma. Thankfully, this is not a real concern with color managed applications like Photoshop. Photoshop corrects the tonal scale so that whether you calibrate to 1.8, 2.2 or native monitor gamma, it will look correct. But, your non color managed applications will definitely be affected. So, I strongly recommend 2.2 gamma for those apps that don't understand color management. If your live your life locked in a closet and never surf the internet, receive emails, nor use non color managed applications, by all means, use native gamma. My standard is 2.2 gamma since I do poke my head outside once in awhile.

White and Black Luminance are the final battlegrounds. Some monitor profiling software products recommend a white luminance of 120 to 140 cd/m² (candelas per meter squared). I find that far too bright for most ambient conditions. If you plan on displaying your prints under "*extremely bright lights*" (like 10 feet from the surface of the Sun), well maybe it makes slightly more sense. Let me explain.

Let's start at the most logical place. Where do you display your framed prints? Most of us hang them on walls in our home, at the office, at a photo show, etc. Most of these locations have what we might call subdued to moderate lighting. If you want your prints to look good in those lighting environments, you start there and work backwards. What's the next step backward? Viewing your finished print in your light booth or under your viewing lights. So, you want to adjust your viewing lights to give you approximately the same light intensity as "normal display lighting", at least for overall assessment. (Yes, you will hold prints closer to the light closer when inspecting details closely). The next earlier step is viewing the image on your monitor, prior to printing, probably in "soft proof" mode.

Let's say you have your monitor set to what I consider a blindingly bright 140 cd/m². You edit your file until it looks perfect.... great shadow separation, bright highlights, good saturation, etc.

Then you print, and what do you see? In a word, MUD. The whole image looks dark, shadow detail is gone, even ¼ tones look dark. What happened? Well, since your monitor was set to an inappropriately bright level (far brighter than you will ever get from a sheet of opaque paper with reflected light), you naturally decided to darken up the entire tonal scale, since it looked so 'washed out'. You changed the "numbers in the file" to be darker, and when those numbers were reliably and accurately sent to the printer using your custom profile (which I trust more than monitor profiles), it came out predictably dark. As you bring your print closer and closer to your viewing light, the increased intensity of your light "opens up" the shadows somewhat and helps offset the darkness you see in your print. If you viewing light is bright enough, then it may actually look more like it did on your monitor.

9 times out of 10, when someone complains to me about blocked up shadows and overall muddiness in their prints, lowering the white luminance of the monitor magically solves their problem.

The graphic art standard in prepress has been 5000K, 1.8 gamma and 80 to 90 cd/m² for years. It took me 2 years of learning, trial and error to get to the same place. You can discount the 1.8 gamma these days, since color managed applications like Photoshop now adjust for gamma. It didn't used to. But....they don't adjust for color temp and luminance.

Black luminance is the final major barrier to a good tonal scale and good monitor to print matching. Most "average to good" LCD monitors have only one analog control ~ the intensity of the backlight. When you raise the white luminance to a brilliant 120 or 140 cd/m², the black luminance creeps up along with it, though not necessarily in a linear fashion. High end monitors have separate controls that allow

much more accurate control of the black point, and if you have one, that is a good thing. If not, you will probably find that setting the black luminance around 0.25 to 0.35 cd/m² will give you a reasonably accurate black point. If your monitor and/or profiling software don't allow you to set the black point separately, then it will fall where it falls. Setting your monitor white luminance to around 90 cd/m² will usually result in a black luminance that is close. Of course, CRTs allow control over both points, just like high end LCDs.

Ambient lighting, especially if it reflects off the face of your monitor, can impact the perception of black, so that always needs to be considered. Consequently, it remains a good idea to work in a reasonably dim room (not in a cave or total blackness) and shield your monitor from stray light sources.

So, my recommendations after hundreds of hours of experimentation and testing remain as follows:

Color temperature

5000°K to 5500°K (mine is set to 5200°K)

Gamma

2.2

White Luminance

80-100 cd/m² (mine is set to 90 cd/m²)

Black Luminance

0.2 – 0.4 cd/m² (mine is 0.25 to 0.3 cd/m²)

If you display your prints under individual bright lights or in a very bright room, you may wish to use 100 cd/m² for white luminance, but I wouldn't normally go much higher. If you display prints outdoors, you may choose a higher monitor temperature, like 6500°K, since daylight is often cooler than artificial lighting. There are a lot of factors at play here, so you need a little flexibility. But, as I mentioned earlier, the range is generally narrower rather than wider.

I might as well discuss the subject of banding, since it is bound to come up. Most LCD

monitors fit 256 shades of gray into their 8 bit space. This is the very best you can hope for from an 8 bit monitor when you leave it set to its native white point, native gamma, etc. We'd all prefer a perfectly smooth monitor, with perfect grayscale, no crossovers, maximum gamut, etc. But ask yourself this one fundamental question...which is more important, a perfectly smooth gradient ramp or accurate color and tonal range? I don't know about you, but I'll take accurate color and tonal range every time, even if I have to sacrifice a little smoothness or a teeny bit of gamut to get it. If you demand the best of both worlds, be prepared to buy a high end monitor and video card.

Finally, if you *are* happy with your monitor to print match using 6500K, 2.2 gamma and 120 cd/m², or another set of parameters, I say go for it. Your vision, lighting, monitor, etc, may be different, and it's the complete system that counts. As long as you don't undermine the tenets of color management, and maintain true portability, use what works!

Using your Custom Printer Profiles

Finally, it's time to print. For this example, I will be using Adobe Photoshop CS2 and my Canon iPF6100 inkjet printer. I have accurate profiles for my LCD monitor, a good custom profile for my paper, and industry standard viewing lights.

1. Editing your file

I always start with a RAW digital camera file when possible and bring it into Photoshop in an appropriate color space. I usually edit my file in one of three different editing spaces. I find that 75% of image files fit nicely inside sRGB, which is a relatively small working space. sRGB has the advantage of being the standard for the worldwide web and is what most computer systems default to (and many service providers, as well). If it is a particularly bright, colorful file, I will often use Adobe RGB. Those are my two standards, partly because they are nearly universal, and partly because they cover most of the ground that needs to be covered. I rarely, if ever use ProPhoto RGB,

Wide Gamut RGB, or other ultra wide editing spaces. They simply have too much baggage, must be edited in 16 bit, and create other issues that don't need to be discussed in this paper.

The other space I like is PhotoGamut RGB, which is different from the others. PhotoGamut RGB is a table based editing space, perceptually uniform, supports ALL rendering intents, and is shaped just like a custom inkjet profile, only a little larger. In fact, PhotoGamut RGB contains a lot of printable colors that Adobe RGB lops off, but it doesn't share the baggage and liabilities of the super wide editing spaces. It is a GREAT space for editing files, **IF** you care primarily or only about printed output. Conversions are gentle, translations are more accurate, there are few surprises, and the results are superb, but there is one minor potential shortcoming you should understand. Paper white can never be as white or bright as a monitor white, so PhotoGamut RGB intentionally, and appropriately, discards those unattainable bright whites (since it was designed specifically for printed output). It was designed to encompass the entire range of printed gamut, including traditional and digital presses, lightjets, inkjets, lasers, dye sublimation printers, etc. And it does a pretty good job of it. But, if you want to post your jobs on the web or email them and maintain the maximum possible dynamic range of a "monitor" (which uses bright backlighting) you will give up a little extra "pop" in the highlights. Of course, you can convert to sRGB and throw a quick curve at the file to get it back, but if the web is your primary goal, it would be best to stick with sRGB from the beginning.

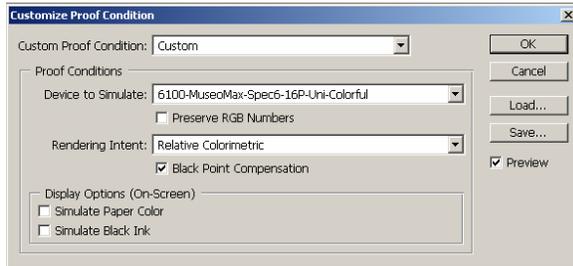
Using one of these editing spaces, edit the file until you get it just right ~ good solid blacks, good shadow separation, bright whites, neutral grays, good color saturation, etc. Save your file.

2. Soft Proofing

For this example, let's assume you have decided to print this image on Crane Museo Max matte fine art paper using your new custom profile. I will assume you have already installed your new

profile in your Operating System's normal color profile folder.

In Photoshop, with your image open, go to View > Proof Setup > Custom, and a new window will open, similar to the one below.



In the box, “Device to Simulate”, you will have choices. My choices are 6100-MuseoMax-Ch+, 6100-MuseoMax-Colorful, and 6100-MuseoMax-MP (which is what I named my profiles when I created them). One uses ProfileMaker’s “colorful” algorithm, one the “chroma plus” algorithm, and the last uses the Monaco Profiler algorithm. For now, choose the MP (Monaco) algorithm. Leave Preserve RGB numbers Unchecked, and make sure Black Point Compensation IS checked. For the moment, leave Simulate Paper Color and Simulate Black Ink unchecked. The final selection will be your Rendering Intent.

You will want to try both Perceptual and Relative Colorimetric rendering intents to see which *initially* looks better (use the Preview checkbox to toggle between the original and the soft proof preview). Now, try the other algorithms with both Perceptual and Relative Colorimetric.

You will find that most profiles (for a given paper/ink combo) look very similar or identical with Relative Colorimetric, but they may look very different with Perceptual rendering. Once you have decided on the one you initially like best, click OK.

You will now see on your monitor a representation of what your print will look like on that paper (*soft proof*). The representation will only be as good as all of the links in the chain, ie, monitor profile, printer profile,

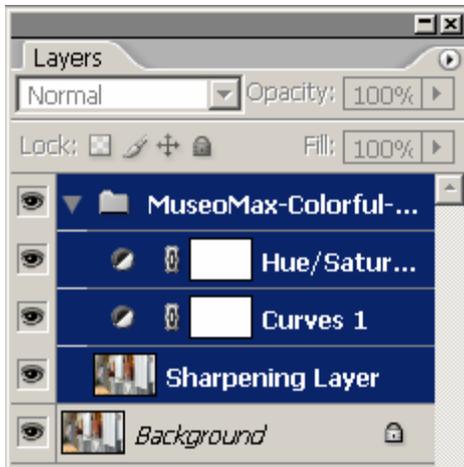
ambient lighting, viewing lights, etc. I strongly recommend that when soft proofing, you keep your ambient light fairly dim, because reflections off the monitor and point light sources in your peripheral vision can wreak havoc with perception.

3. Tweaking the file for printing

When printing on glossy, semigloss and other high Dmax, wide gamut papers, you won't generally notice huge changes from the original file to the soft proof. Matte fine art papers, however, have a much smaller dynamic range, weaker Dmax, smaller color gamut, etc, and your soft proof may look weak and dull in comparison to the original. Part of this is the sad truth of printing and reflected light, but it is really accentuated by doing an A/B comparison.

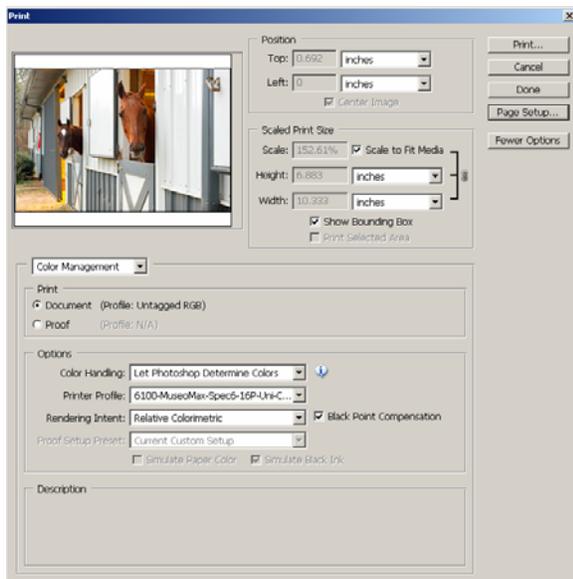
Regardless, you will want your final print to reflect the best the image has to offer on this particular paper. So, I usually apply some minor corrections to tweak the black point, shadows, highlights, and to add a little snap to the final print, *while the soft proof preview is visible on screen*. I usually start with a curves adjustment layer. Sometimes I may increase the saturation with a Hue/Saturation layer. I may even add a little sharpening, globally or locally. I usually save these “tweaks” in a Layer Group and name it something like “MuseoMax – MP – Perceptual” so I know exactly what it was used for, namely printing on that MuseoMax paper, with the MP profile and with Perceptual Rendering intent. (To create a group, shift-click until all the adjustment layers are highlighted in the layers palette, then use the call out menu and select New Group from Layers. Now you have them all grouped together.)

Your adjustments will never bring you back to the full color and dynamic range of your original image, since this paper/ink combination just can't reproduce some of your original colors and dynamic range (which is why you tweaked the image). But it will improve the image and help you achieve the best print possible on this particular paper. Save your image if you wish, preferably as a Photoshop PSD file, maintaining all your layers for future editing.



4. It's Time to Print

Finally, it's time to print your carefully prepared and 'tweaked' image. In Photoshop, select Print with Preview and set scaling, paper size, etc.



In the drop down box, select Color Management, and under options select the following:

Color Handling - Let Photoshop Determine Colors

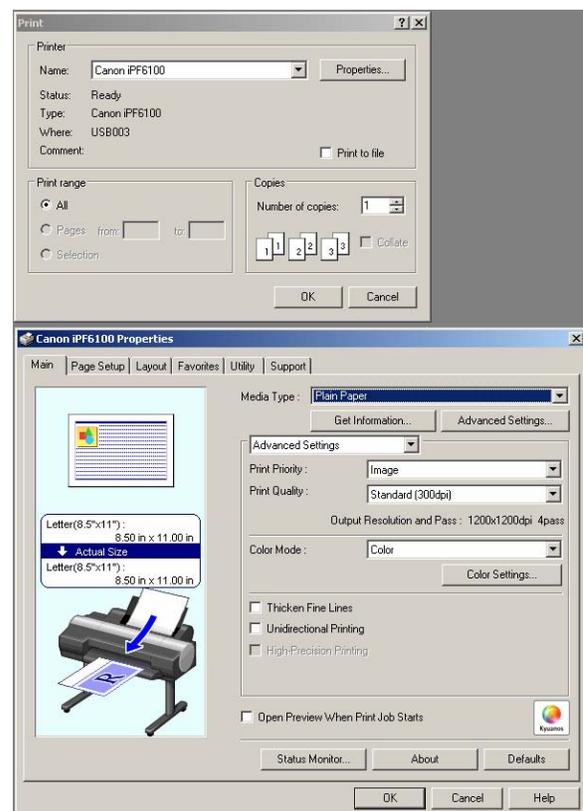
Printer Profile - 6100-MuseoMax-MP (or whatever profile you used for soft proofing)

Rendering Intent - Perceptual (or whatever rendering intent you used for proofing)

Black Point Comp - Make sure this box is checked

By selecting the above, you are telling Photoshop to convert all the numbers in your file "on the fly" before they get to your printer driver. Photoshop will look at the original editing color space (sRGB, Adobe RGB, PhotoGamut RGB, or whatever) and it will look at the printer profile and rendering intent you chose in the above boxes, and make adjustments based on both profiles. If your monitor and printer profiles are very accurate, your print will look extremely close to what is on your monitor.

Now, we need to discuss your printer driver settings. When you click the Print button, control will be handed from Photoshop to your printer driver. Pick your printer from the drop down box (I chose Canon iPF6100) and then click Properties.



Hopefully, you remembered my advice to save all the custom settings in your driver when printing your target for profiling. If so, just activate those settings, and you should have the

correct media setting, dpi, speed, quality, etc all ready to go. Make CERTAIN that color management is set to OFF in your printer's driver. Why? You already made the color adjustments in Photoshop's Print with Preview dialog box. You only want to make the conversion once. If you do it twice, you'll be 'double dipping' and you will get ugly color. If you don't do it at all, you'll get ugly color. Do it once and you will get great color. It's like asking someone for a cup of coffee. They put in two lumps of sugar, and not knowing this, you also put in two lumps of sugar. Double correction...not good.

You can actually do the conversion in EITHER Photoshop OR your driver, **but not both**. Some printers, such as my Canon, have a special plugin that entirely bypasses Photoshop's color controls for printing. In this case, I do the final conversion inside the plugin INSTEAD of in Photoshop. *The rule is always, one or the other, but not both.*

Once all is set, click the Print button. Let your print dry for half an hour before critical evaluation (no, I can't ever wait either, but colors do shift somewhat during drying, which was why we waited before profiling your target).

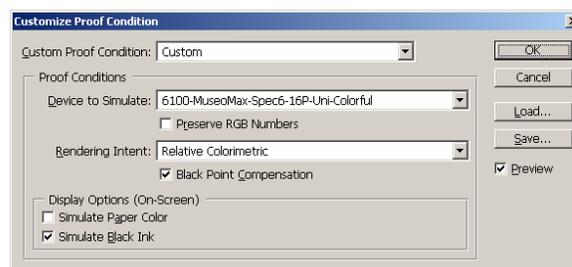
5. Evaluating you Print

OK, it's time to see how you did, and how your profile performed. So, bring your image up on your monitor, soft proofing with the same exact profile, rendering intent, and final "tweaks" as used to print the file. Display your print under your 'moderate intensity' viewing light or in your viewing booth (standardized 5000K viewing lights are highly recommended for accuracy).

First, it is unreasonable to expect an absolutely perfect match, no matter how good your profiles are. You are comparing apples and oranges... transmitted RGB light from a monitor to reflected light off paper using CMYK dyes or pigments. Ink on paper has a limited range compared to a monitor, and besides, ambient light, viewing light intensity and color, and a whole host of other variables come into play.

But, if you calibrated and profiled your monitor to my recommendations, you have taken a big step in the right direction. You should see your tonal range displayed correctly, and the neutrals should be pretty close to right on, and your colors should also be very close. If your print looks muddy and dark in comparison to your monitor, perhaps your monitor is still set too bright, so try increasing the intensity of your viewing light, or moving the print closer to the light source.

If no matter what you do, your blacks seems weak in print compared to your monitor, then from the Photoshop menu, select View > Proof Preview > Custom.



Leave everything unchanged, but click the Simulate Black Ink checkbox so it is now checked. You will see the dynamic range of your display become a little weaker than before and the blacks will look a little more washed out. This checkbox is Photoshop's way of reducing dynamic range in an attempt to simulate the effect of black ink on low gamut papers, such as matte fine art papers, newsprint, etc.

Frankly, I find the "truth" often falls in between having the Simulate Black Ink box checked and unchecked, so I will often toggle it on and off and try to split the difference. In my experience, I find it best never to use Simulate Black Ink on higher gamut papers (glossy, semigloss, luster, etc) and find I get the best match. With lower dynamic range papers, I toggle it on and off. The black luminance setting of your monitor is ultra critical in evaluating blacks, especially for low gamut papers. So is ambient lighting, hence my recommendation for turning lights down very low for final soft proofing. Monitor to print matching is a tough game, and monitors

and prints are entirely different technologies, but it gets better all the time. It isn't perfect, but it is very good.

Algorithms, Rendering Intents and Conversions

And finally, I'll offer some thoughts on the above algorithms, rendering intents and color conversions. I usually supply one or more profiles for each paper. These 'algorithms' are formulas, or recipes, that the software engineers devised for dealing with colors that are out of gamut. But, to understand them better, we need to touch on rendering intents first.

Rendering Intents

If you printed a fairly flat image with limited dynamic range and color gamut, there is a good chance that all the colors displayed on your monitor would reproduce accurately on paper. In color management parlance, all your file's colors would be considered 'in gamut'. But, due to the limited dynamic range and color gamut of ink on paper, we often have to deal with colors that lie outside the gamut of the printer/paper/ink combination.

There are multiple ways to deal with these 'out of gamut' colors, but we will focus on the two most important.

Relative Colorimetric rendering reproduces all 'in gamut' colors most accurately. It then takes the 'out of gamut' colors and brings them to the closest reproducible color of the destination profile (in this case, your custom printer profile). At that borderline where 'in gamut' meets 'out of gamut' colors, things change and detail and color differentiation can be lost. Relative Colorimetric stresses accuracy over relationships. Relative Colorimetric is often the best choice for things like corporate logos, illustrations, or files with an insignificant or small segment of colors that are 'out of gamut'. Your image will show less color and tonal shift overall, but those colors that are out of gamut may show less differentiation and detail as they pile up on one another. If they are insignificant, then Relative Colorimetric is probably the way to go.

The second common way to deal with 'out of gamut' colors uses Perceptual Rendering. Perceptual rendering looks at the brightest and darkest colors, and at the most saturated colors, then *scales all colors and tones proportionally* so they fit into the boundaries of the destination color space. This means that nearly *every* color will shift somewhat. Perceptual intent stresses color relationships and spacing over absolute accuracy. Perceptual often works well for photos that have a LOT of 'out of gamut' colors, since it preserves relationships and leads to a more natural presentation. Its downside is that you will often see more of an overall density and saturation shift than you do with Relative Colorimetric.

The only good way to determine which rendering intent to use is to try it. Some images look better with Relative Colorimetric and some look better with Perceptual. But one way or another, you have to cram the data in your file into the destination color space (usually ink on paper). And remember, you can apply curves and other corrections in Photoshop to tweak the result, so pick the one that looks best overall as a starting point.

Algorithms

Now, we can get back to how the algorithms "generally" behave. As mentioned, these are formulas or recipes used to deal with these rogue colors that are outside of your ink/paper gamut. The ICC (International Color Consortium) specification did a good job in nailing down the definition of Relative Colorimetric rendering. Consequently, the various algorithms look very similar when using Relative Colorimetric Rendering (be sure to use Black Point Compensation with RC rendering).

Perceptual, however, is a different story entirely. The ICC decided to give vendors a lot more leeway in their Perceptual recipes. So, different vendors, and different algorithms from the same vendor, can have very different results with Perceptual rendering.

I find the Chroma Plus algorithm *usually* preserves more accurate color and detail in the highlights, but it shows a larger shift in density

and saturation in many images. Consequently, your ‘tweaks’ may include beefing up the shadows and midtones, and possibly adding a little extra saturation to recover what was lost.

Colorful, tends to show less of a density and saturation shift, but sometimes at the expense of color accuracy and highlight detail, and sometimes some unwanted shifts in the yellows and greens.

I find the Monaco perceptual rendering to be the most accurate and pleasing, but you may still notice some shift in tonal range and saturation.

It varies from image to image and the only way to know for sure is to try it out. That’s why I sometimes provide multiple profiles.

Conversions

A conversion, in color management, means changing numbers in a file, whether it be ‘on the fly’ (like when sending a job to print), or whether you use Photoshop’s *Convert To Profile* command. A conversion always requires two profiles...always. There is a source profile and a destination profile.

The source profile is usually an editing space, such as sRGB, Adobe RGB or PhotoGamut RGB. The destination profile is usually a custom printer profile for an inkjet or some other device. Usually, but not always, the source space is larger than the destination space. Regardless, they usually are not shaped exactly the same, and they two spaces overlap. RGB monitors are strongest in the red, green and blue primaries that define their endpoints. CMYK type printers are usually strongest in cyan, magenta and yellows and less robust in the red, green and blue components. Conversions need to reconcile these differences.

It is always best to use the smallest color space that fully contains all the colors of a file when editing. If you want a drink of water, there’s no need to reach for a 55 gallon drum; an 8 ounce glass will do just fine, and it is in fact better and easier to handle. You don’t fire up the steam shovel when you need to move a cubic foot of dirt. If you want to meter cubic centimeters of

fluid, you don’t use a 10 inch valve. It’s the same thing with editing spaces.

If you use a huge editing space, such as ProPhoto RGB (which is truly massive), you have some pluses and, at least in my opinion, some significant minuses. First, if you don’t work in 16 bit, you will experience problems with banding and posterization, since the distance between points is so far apart. Second, due to the wide spacing, you generally have less control, since a small move makes a much bigger difference. Third, it goes WAY beyond the ability to display on any monitor, and well beyond more modestly sized editing spaces. You may be editing some weird colors into your file and you won’t even see them until the print ushers forth from your printer. Fourth, when it comes time to convert to your printing profile the difference in profile sizes will be so huge as to force very larger profile conversions. These can introduce bigger shifts during conversion and some unpleasant surprises compared to a more modest, but adequate, editing space.

If you are working on a typical image, sRGB is usually fine. A very bright colorful image often demands Adobe RGB. PhotoGamut RGB does better than both, providing print is your primary intent, but it isn’t that bad for the web either, though you do lose a slight amount of ‘zing’ in the highlights. There is the occasional image that *may* benefit from ProPhoto RGB, especially super bright, saturated yellow flowers and things like that, but they are few and far between. Me? I generally use Adobe RGB or PhotoGamut RGB for those bright, colorful images.

As with all things, experiment and decide for yourself what works for you. If you like wide gamut spaces, who am I to discourage you? Go for it. But, if you start having troubles, or start seeing some unusual, unpredictable results, think about what is written here and give it a try.

RIPs

I promised I would touch on RIPs before ending this article. Personally, I avoid RIPs whenever possible. I have used a bunch over the years, and when implemented correctly, they can be

very powerful and provide great output. But, they tend to be expensive, poorly supported, buggy, irritating, time consuming, and fraught with more than a few problems. What they do very well (again, if properly designed and implemented) is allow the user much better control over ink limits, dithering, ink balance, crossover points, gray balance, black generations, linearization, shadow detail, layout options, etc. But it takes time, experimentation and work. RIPs are particularly helpful with some papers and inksets, especially if the driver does not have a suitable setting for the particular paper you are trying to profile. And, this does happen from time to time. It has happened to me more than once.

RIPs are a very deep topic unto themselves, so I won't attempt to delve into it too heavily here. OEM drivers attempt to build ink limits, linearization, ink balances, etc, into their media settings. Drivers have gotten better and better over the years, and more OEMs are providing a greater range of settings. For example, my Canon iPF6100 has 10 custom settings that cover a lot of ground and provide more flexibility than most drivers have in the past. They also have about 50 other media settings for a wide array of Canon media (too many, frankly). I can usually find a media setting that gives me great output, Dmax, color gamut and excellent shadow and highlight detail, but it does require some testing as outlined earlier.

But, RIPs require a large investment of time and effort too. You have to determine overall and individual ink limits, you must linearize and make sure you don't go too far into the hook of the chroma curve. You need to establish the correct dithering pattern, set ink crossover points, etc. After all that, you then print and read a target for profiling.

It's a lot of work. Sometimes it is worth it and sometimes it isn't. In general, my opinion it usually isn't worth the effort. In fact, I often found I got BETTER results from the driver than I did from a RIP, even after days of trying to perfect settings. I'm sure some people will take issue with this statement, and perhaps they have the exact right RIP and experience to get the

most from their printer. I know it can be done, but I question whether the results are worth the effort.

For most of us, even those of us interested in high end fine art quality prints, the driver is often the best way to go, and not only that, it comes free with your printer. And these drivers are getting better and better, as are the printers.

Scanners, Presses and Other Devices

I'll wrap up by briefly discussing other output devices. Some devices, such as presses, require a CMYK data stream. If it involves a RIP, it is almost always CMYK driven. Lightjets, being a photographic process, require RGB data.

Regardless, these output devices are all equipped with software, or an intermediate step, that make changes to the file. A driver or RIP converts digital data into instructions so that the printer or plate maker can fire dots of ink or scribe a microscopic dot on a metal plate. A lot of magic goes on underneath the hood of a RIP or driver. The profile we create must take these factors into account. The subject gets deep fast, and is way beyond the scope of this paper (which is already too long). But, as long as we are careful to calibrate our equipment and maintain the stability of our *system*, we can profile a press, laser, lightjet, or Indigo just as we do an inkjet. Some of the steps differ due to the equipment involved, but the principles are the same. And often, we profile the commercial printer's proofer, instead of the press, since the proofer is much more stable and repeatable.

For who have invested in high end scanners, good scanner targets and software are important. Again, the principles discussed apply equally to scanning.

Hopefully, this article has adequately explained the principles and steps involved in achieving good custom profiles. The field continues to evolve as we learn more about color and how to control it.