

Color Accuracy -- Problems and Solutions

Since the inception of the PC in 1981 we have demanded more and more color. First color was used to make games more interesting, and then to make programs easier to use. Color is now exploding into most of your documents and presentations taking them to the next level of professionalism. We started out with 4 colors and moved to 8 then 16 colors. We graduated to capabilities as high as 256 colors; and now we have rocketed into the stratosphere with 16 bit (65,000) and 24 bit (16.7 million) color. And all for what? More accurate and realistic representation of the world around us, or the world we would like around us. We have now raised expectations for color reproduction on a PC to the point where we as consumers are driving technology again. If you have ever tried to scan, create or print anything in color off a PC, you know the horrors that can creep up. Washed out images, colors askew if not actually wrong, and of course accuracy of gradients are just a few of the problems.

We would like to first address some of the limitations and constraints of the color technologies currently available on the PC platform due to the technologies, and hardware, and then some solutions. For some, this will be too technical for others, not technical enough. The intent is to introduce new ideas to solve some of the problems that may be encountered.

Keep in mind that this is going to be an arduous task. Some of the factors involved are ambient room lighting, wall and ceiling color and reflectivity, video card, monitor, printer, software and scanner. This is all without mentioning the Red Green Blue to Cyan Yellow Magenta black conversion problems. Then we have gamma correction, white balance, color temperature and phosphor chromaticity to take into consideration. Even considering this, we have to be aware of the gamma of the monitor, video card, scanner, printer and the image itself. With this many variables, one can see that the likelihood of getting screen images that match printed output perfectly is slim if not impossible. This would be a good time to explain several terms that are going to be used in this article, and that you will see along your adventure in color calibration.

GAMMA

The light output from phosphor is not linear to the video driving voltage. It is proportional to the video driving voltage raised to the power of "gamma". This means that brighter color is expanded and darker color is crushed. In monitors and TVs gamma correction circuitry is included to minimize the effect, thereby giving a truer representation of the video driving voltage input to the CRT. The gamma figure given here is a corrected gamma function. Uncorrected gamma in phosphor tubes is usually 2.2. The closer the gamma is to 1 the "truer" the display.

Formula: $L=V^{(\text{gamma})}$; light output = video driving voltage raised to the gamma.

Gamma is typically written as just one number. For instance, for the NEC monitors, the gamma standard rating is: 2.46.

CIE chromaticity coordinates

CIE - international commission on illumination that defined a chart with a coordinate system used to specify color.

White point

In CIE coordinates is the color that the monitor displays when each input channel (RGB) is at the maximum voltage level (white). Also expressed in Kelvin (K).

Phosphor colors

In CIE coordinates is the color the monitor displays if only one (RGB) channel is active. Or the color the green, blue and red phosphors emit respectively.

Example:	<u>B22 (P22) Phosphor</u>	<u>Persistency</u>
	<u>X</u> <u>Y</u>	
	red .610 .350	1 mSec
	green .307 .595	150 μSec
	blue .150 .065	100 μSec

White temperature

In the old days all sources used for light were "hot" objects. Candles, sun or tungsten filaments for example. The light emitted from these object is related to the absolute temperature given in K (Kelvin). It was customary to express the color of a light source using the color temperature. The white temperature data listed relates the white point data to the older method of related colors - color temperature.

Note: NEC Technologies standard policy concerning factory ship condition white point is as follows:

<u>CRT Size</u>	<u>White Point K</u>	<u>CIE Coordinates</u>
15 Inch	7500 K	x = 0.300; y = 0.315
17 / 19 / 21 Inch	9300 K + 27 MPCD	x = 0.281; y = 0.311
17 / 19 / 21 Inch	9300 K + 8 MPCD	x = 0.283; y = 0.297

Many MultiSync monitors have the capability of changing their white point setting which is controlled through the user front panel controls.

To start off, set PC variables that are going to be static and available. For instance, Adobe PhotoShop asks in its Preferences settings for monitor gamma, white temperature and phosphor chromaticity. These variables should be easily obtained from your monitor manufacturer. The same goes for setting up the printer variables in the printer section. After this is done, we will have set a baseline to work from. This way, the software is aware of, and makes changes in it's own configuration based on any hardware anomalies that it is aware of based on the preferences that you have made.

After setting the PC to the baseline, the next order of business is to make the room the right ambient light condition for working on color images. This is quite subjective, but one must keep in mind a couple of facts. If there is a window in the room, the ambient light will be changing all during the day. Morning light will cause a reddish hue, and mid afternoon lighting will cause a yellow cast. If blinds are used, be sure to use blinds that block light as opposed to filtering it through another color.

Also consider the room color. If the room is painted in the standard eggshell or off-white, reflected light from the walls and ceiling will cast a yellowish tint to your printed output. A room painted white would be better for proofing the hard copy. Then there is the issue of lighting. Incandescent light bulbs will cast a yellow to orange hue, and halogens a blue hue. Fluorescent lighting is closer to white when diffused. With fluorescent lighting, one may experience a "flicker" effect on the monitor due to a low refresh rate. Again, keep in mind that the majority of this is subjective since the measuring device is the human eye.

If we were to use a calibration cup (which will be discussed later), the cup uses a suction to attach to the monitor to block out all ambient light. Using that logic, the best room for viewing monitor editing is a room painted black with no windows or lights, and the best room for checking your proofs is a white room with many fluorescent lights and no windows. Our personal preference is to set the room with no windows, or heavy blinds or shades, paint the room flat white, and incorporate fluorescent lighting. Then turn the lights out for working on the PC, and turn them on for checking the proof. Now we have the PC set to the baseline hardware and software configuration, and we also have the room setup. Next is configuring hardware to hardware.

First, consider your printer (or your service bureau) output to be the standard that you are trying to match. Print a test page you are happy with, and adjust your printer first to get the right balance of color and contrast. Then work on matching the software, monitor and video card to that output. There are several ways to accomplish this.

The video card and monitor combination are mentioned as a system, because they work in conjunction with each other more closely than they do with the printer. They also are more adjustable and configurable than the current printers.

Find a video card and monitor that function well together. For image editing and DTP, currently the trend is toward 1024 x 768 resolutions, and to a lesser but growing degree toward 1280 x 1024 resolutions. To avoid flicker from other electrical appliances and fluorescent lighting request a refresh rate of 70Hz (Hertz) or better. The reason for this is that the fluorescent lights are "flickering" on and off at 60Hz or 60 times a second. If the monitor uses a 60Hz refresh rate, that means that the phosphors are being excited from top to bottom 60 times a second as well. The phosphors at the top of the screen start to fade slightly before the electron gun gets back to the top to re-excite them. If the monitor is "flickering" and lights are "flickering" a strobing effect takes place that is quite annoying. There are video cards available now that are programmable. Companies like NUMBER9, Hercules and Matrox offer video cards that have timings for popular monitors programmed in, but are also capable of being "tweaked" to get the most out of the monitor/card combination.

For color accuracy, 16 bit (65,000 colors) is typically sufficient, but for more detailed editing ask for 24 bit (16 million colors) capability. The key is to ask for a video card in this way. "I would like a video card that will produce 1024 x 768 at 70Hz or better and 24 bits per pixel, all at the same time." This should ensure a product acceptable for all aspects of image editing and desktop publishing.

With the appropriate video card and monitor combination, the system can be almost infinitely configurable with respect to color. For instance, Video cards like #9GXE and the Matrox MGA are bundling drivers for Windows® that incorporate color "tuning". This utility basically changes the intensity of the Red, Green or Blue output from the video card to change the overall color of the screen, meaning everything on screen will take on a color hue change. If you have a TIFF image of a person's face on screen and it is washed out, but printed fine, you may want to increase the RED on screen. This will add depth to the face image, but the white background will take on a reddish hue.

Then there are monitors that incorporate that type of "color matching" into the hardware design. By pressing buttons on the monitor one can set the overall screen to a different hue to match different colors to output. These solutions are the quickest, easiest and least expensive. They will afford some utility with color matching and accuracy. This is the same type of adjustment that the video board offers, but this option can be used in conjunction with the board for more specific tuning. Consider that the video board is tuned to a reddish hue, the monitor also has settings that can be saved. For instance if one is using PhotoShop and PhotoStyler, because of the way each package sets up the video and the monitor, there may be a need to have two different monitor settings. One may require a boost in the Blue, and the other may require a boost in the Red. Again, these are gross changes to the overall screen color, temperature and hue. These changes do not affect the colors on the output device. This is why they are so important. The changes made to the software in the preferences section are also gross calibrations, and should not affect the output either.

Since the conversation has gotten to video, the next step is obviously the monitor. To manage color correctness best the monitor has to be flexible. For instance, monitors with an "etched" tube may well reduce reflection and glare, but they also dull the image on screen, thereby changing the actual color that you see. On the other hand, a polished tube allows all light/color to pass through the screen without obstruction, hence a truer representation of the color. The tradeoff here is that the polished screen reflects more light back from the surrounding room. This is another reason for shutting lights off in the room.

The monitor should also support multiple resolutions and refresh rates. Also consider a monitor with high technology display components inside the tube itself. For instance the addition of an Invar Shadow mask will allow the monitor to run brighter and with more contrast. Because Invar is a new metal, it is less susceptible to distortion and wear and tear. This can help manage the problem of drift. Over time, the monitor color will "drift" off of the colors that were originally set. Lower quality monitors will show significant drift over weeks as opposed to years. The video card isn't susceptible to drift since it is a digital device, and the component have the look up tables on a chip. A considerable amount of money is going to be spent on this system, consider buying into the idea of futures. Granted the monitor is only being used for 1024x768 right now, but you will no doubt want higher resolutions down the road. Why go through this nightmare again? The recommendation is to purchase at least a grade more than you need right now.

The most definitive PC solution at this point that we have seen is the use of a calibration cup. Companies like Sequel Imaging create a device that plugs into certain video cards like those provided by Matrox or Hercules and attaches to the monitor screen and the hard copy printouts. The suction cup first measures the features of the printed page with respect to color, density, contrast etc., and establishes a baseline to set the video card to. The suction cup is then attached to the face of the monitor and a series of displays are measured for the same characteristics. This information is fed back to the software, and the software rewrites the color look-up table on the video card to more closely match the hard copy output from the printer. This sounds like the perfect solution, but the major limiting factor is cost. The video cards that have this updating capability are typically over \$1000 and the suction cup and software are usually between \$1,500 and \$2,000.

Our recommendation is to find a solid image editing package like Adobe PhotoShop or Aldus PhotoStyler that takes color anomalies into account. Both software packages allow one to change the ever nebulous GAMMA of an image. A definition for "gamma" or as is more often seen, "gamma correction", is a very difficult thing to come by. In trying to simplify the explanation of it, we have distilled it down to the idea that gamma takes into account several elements of the image. These attributes are color saturation, contrast, brightness etc. These are normalized on an X/Y axis as a linear line with a 1:1 ratio. As mentioned before, hardware has a gamma, and so does the image.

That is why when we started this journey, we set the software to the monitor gamma. As we are trying to approach 1, if we enter the monitor gamma a 1.014, the software will move the other way on the gamma scale and set itself up for a gamma of .986. This will then average out to the 1 that we are looking for. For the image, the gamma correction is dynamic, and also changes the hard copy output of that image. You will no doubt note that when gamma for an image is changed several things occur. The image may seem to get darker or lighter, contrast may seem to increase or decrease and colors may seem to become more or less intense. The best way to handle gamma correction is to find out the gamma of the device the image was obtained from, and working it backwards to that 1:1 ratio.

This may mean the image has a gamma of .65. If that is the case, to normalize the color content back to something that is desirable, one would start by gamma correcting by 1.35. This is most easily seen in the software implementation. Gamma is something to be aware of in color correcting, because in a normal sequence of events, an image might be scanned. The scanner uses a CYMK color space and has a specific gamma. The image is brought into the computer and shown through the video card onto the monitor. Both working with RGB and with their own gamma. Then the image is output to a color printer using CYMK and running it's own gamma. You can see that you may have to adjust gamma for three devices within the software. The gamma numbers requested by the software should be available from the hardware manufacturers. Now, gamma can be changed dynamically for the image, or it can be changed overall for the software package. Most of these packages ask for the monitor gamma. When this is entered, the software sets the defaults up to present colors on screen with the monitor gamma adjusted for. If one wants to change the gamma of the image, this can be done for exclusively that image as well (this would be done if it were an inferior scan).

To adequately deal with all of the problems inherent in matching color output to color on screen, we recommend flexibility. Keep lighting as close to white as possible. Choose a video card that can adjust colors through software drivers and save those changes into files that can be recalled, a monitor that can change colors through hardware adjustment and save those mode changes and software that can account for hardware GAMMA correction and dynamic image GAMMA correction.

Now that this has been addressed, are you ready for scanners?

