

The Effects of Clear Toner on the Color Gamut of a Digital Press

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Abstract

The Canon imagePRESS C1+ is a digital press capable of printing four-color process toner, as well as a special clear toner. This clear toner can be used to create watermarks in images for security printing as well as elegant designs. When printing this clear toner over or under other colors, it is imperative to understand how it will affect their color gamut, because it can change how an image looks. This change can even be observed with the human eye.

To determine exactly how clear toner affects the color gamut, the imagePRESS first needed to be profiled correctly in order to achieve accurate results. The chart used for this was the ECI2002R CMYK test chart. Before profiling, a set of five substrates was also chosen. Substrates used include one with a smooth finish, one with a gloss finish, and one with a matte finish. These substrates also varied in weights, giving an extensive range of options to compare. Each substrate had three different samples; one printed with no clear toner at all, one with clear toner underneath the CMYK toner, and one with clear toner on top of the CMYK toner. Thus, fifteen different profiles had to be created.

Once these profiles were created, their color gamuts could be viewed and compared using software. The GretagMacbeth ColorChecker® was also printed, with each profile applied, on the corresponding substrate. From the GretagMacbeth ColorChecker®, color measurements were then taken and compared. The measurements taken include the LAB values of each color square in order to determine the ΔE between using and not using the clear toner.

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Introduction

The color gamut of a device refers to the range of colors that it can produce (Chovancova-Lovell and Fleming, 2009). No device is capable of producing every color that can be seen by the human eye. There are three factors that affect how we see color and are used to determine where a device's color gamut lies. They include an illuminant (or light source), the sample spectrum reflected off an object, and a standard observer (the human eye) (Sharma, 2004)². These three factors are used to come up with a number of color spaces such as the CIE XYZ color space.

The commission responsible for specifying today's color management measurement systems is the International Commission on Illumination (CIE), because they represent color the same way we see it. One of the color systems developed by the CIE is the CIE 1931 x, y chromaticity diagram (Figure 1). This horseshoe-shaped diagram illustrates the chromaticity (or hue) coordinates of all physical realizable color stimuli (Sharma, 2004). This chart uses x and y coordinates to illustrate where a particular color falls. Finding these coordinates can be done using the following equations. XYZ are derived from the three factors mentioned earlier and represent the tristimulus values red, green, and blue respectively (Madden and Giorgianni, 2008).

$$\begin{aligned}x &= \frac{X}{X+Y+Z} \\y &= \frac{Y}{X+Y+Z} \\z &= \frac{Z}{X+Y+Z} = 1 - x - y\end{aligned}\tag{1}$$

When looking at the color gamut of electrophotographic printers, it has been observed that they normally produce a gamut of slightly more than 300,000 colors (Bohra and Fleming, 2011), with a ΔE tolerance of $\sqrt{3}$ (Chovancova-Lovell and Fleming, 2009). To maximize a device's color gamut, it must first be profiled without any sort of color management. Creating a device profile generally involves five steps which are (Chovancova-Lovell and Fleming, 2009, Sharma, 2004; Madden and Giorgianni, 2008; Adams and Weisberg, 2000):

1. Calibrate your device
2. Print, display, or scan a test chart
3. Measure the test chart
4. Use profiling software
5. Produce a profile

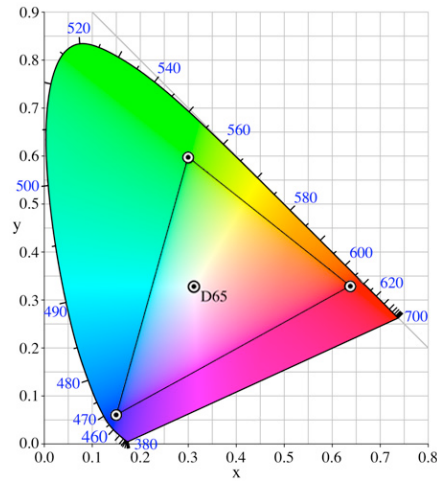


Figure 1. CIE Chromaticity diagram.

Calibrating the device is the most important step, and basically involves adjusting the device to a known manufacture specified starting condition. If a device is not calibrated first, then there is no point in profiling it because the profile will be inaccurate.

Experimental

To analyze the effects of clear toner on the color gamut, five substrates with various basis weights and properties were chosen, as described in Table 1. Each of these substrates had the ECI chart printed on them without any clear toner, with clear toner printed over the chart, and with clear toner printed under the chart. However, before any analysis could be performed, a profile had to be created for each of these scenarios.

Table 1. List of Substrates.		
<i>Substrate</i>	<i>Name</i>	<i>GSM</i>
1	20# Hammermill Bond	75
2	24# Beckett Writing (super smooth)	90
3	60# Husky Opaque Offset	89
4	60# 4CC Stora Enso Cover	160
5	80# Sappi Flo Gloss Digital Text	118

Press Calibration

Before conducting any research on the imagePRESS C1+, it first needed to be calibrated. Press calibration was done in accordance with the press operator's manual (Lowery, 2007). There are three steps to properly calibrate the press. They include balancing the shading correction, which ensures an even print density across the page, adjusting the gradation, and finally a Fiery RIP Calibration that adjusts the color.

Printing the Test Chart

Once the press was calibrated, profiling could be performed. The chart used to profile the press was the ECI 2002R CMYK test chart, which contains 1485 different color patches. To rule out any conflicts between Photoshop and the RIP, the test chart was sent directly to the RIP using Command Workstation 5 (CWS, see Figure 2), a free software package available with all imagePRESS systems. After making sure the ECI was setup as untagged CMYK, it was dragged and dropped into the CWS queue and ready to be printed.

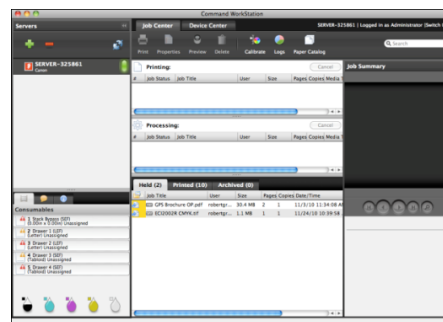


Figure 2. Command Workstation 5 Interface.

To properly create each ICC profile, device color management first needed to be turned off. This is done by right-clicking the ECI test chart in CWS and opening the "Properties" window (See Figure 3). The following are the settings that were used.

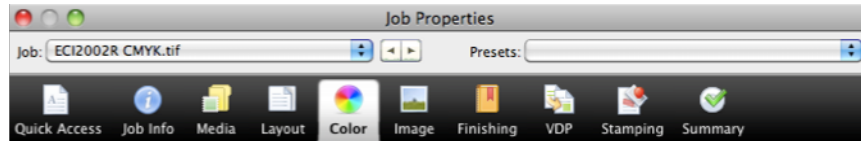


Figure 3. CWS Job Properties Window.

Media

Media Type: *Plain*
 Paper Source: *Drawer 1*
 Paper Size: *8.5 x 11*

Layout

Check the *Scale to Fit* radio button

Color

Check the *CMYK* radio button.
 Open *Expert Settings...*
 CMYK/Grayscale Source should be set to *None*
 RGB Source is *None*
 Rendering intent: *Absolute Colorimetric*
 Uncheck *Spot color matching*
 Under the Gray & Black Processing tab change everything to *Text/Graphics*
 and turn *Pure Black On*
 Output will be ignored since CMYK source was set to none

Image

Turn Toner Saving and Toner Reduction *Off*

Finishing

Clear Coat is *Off*

For the samples with clear toner on top, the Clear Coat option was set to *On*. For samples with clear toner underneath, the clear toner was first printed on the substrate using the Coating function available on the imagePRESS console. The chart was then printed on top of the clear toner using the above settings.

Once all of the properties are set click *Ok*. Then, right-click the job and select *Print and Hold*. This allowed the same settings to be saved for the next profile since fifteen of these charts would have to be printed.

Measuring Test Chart & Profile Creation

Every profile was created using ProfileMaker 5.0. Once open, select the *Printer* tab to get the following options (Figure 4). Under Reference Data select *ECI2002R CMYK.txt* and then under Measurement Data select the *Eye-One iO* or equivalent to measure the test chart that was printed. The measurement

window will popup, select *Patch* for the Mode and leave the Number of Measurements at *1*. Click the *Start* button. To calibrate the device, it will ask you to locate three corners of the test chart (top-left, bottom-left, bottom-right). Once these corners are found, the device will begin to read the chart. Upon completion, the data can then be saved in a location where you can find the data file later on.



Figure 4. Profile Maker 5.0 Software.

Once the chart data have been saved, go back to ProfileMaker and under Measurement Data make sure it is now selected. The following are the settings used to create each profile. Select *Large* as the profile size, select *Neutral Gray* for Perceptual Rendering Intent, and select *LOGO Classic* for Gamut Mapping. Make sure *D₅₀* light is also selected as your light source and uncheck *Correct for Optical Brightener*. Finally, click the Separation button and under the separation dropdown box select MaxK as well as 0% black. After all of the settings have been made, click *Start* under Calculate Profile.

Analysis

After all profiles were created, two main comparisons that were performed. First, was a gamut comparison and was done using a piece of software called ColorThink. This software graphed the gamuts of each profile with clear toner over the gamuts of each profile without clear toner. The second comparison made was an LAB value comparison. Each profile was applied to a GretagMacbeth™ ColorChecker Color Rendition Chart in Photoshop. This is done under the Edit menu by selecting Convert to Profile. The appropriate profile was then selected. Each of the ColorCheckers was printed the exact same way as the ECI to ensure consistency. The LAB values were then measured on each chart and compared using the following equations:

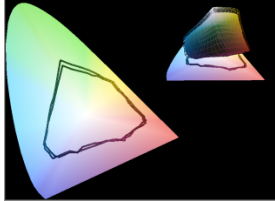
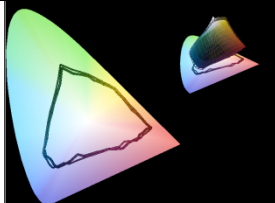
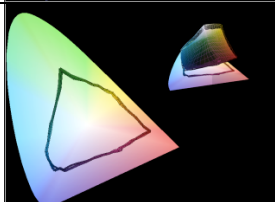
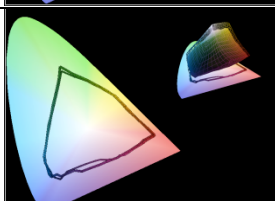
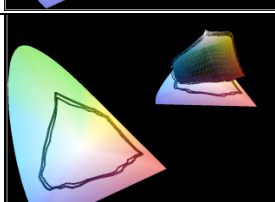
$$\begin{aligned}\Delta E &= \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2} & 2a \\ \Delta L &= (L_1 - L_2) & 2b \\ \Delta C &= \sqrt{(a_1^2 + b_1^2)} - \sqrt{(a_2^2 + b_2^2)} & 3b\end{aligned}$$

Anything with a ΔE under 3 is usually acceptable and means that we cannot distinguish the difference in those two colors with the human eye. From the ΔE we can also calculate the ΔL and ΔC . The ΔL shows the change in lightness and ΔC shows the change in chroma (or saturation).

Results & Discussion

The initial results of this experiment were unexpected and showed how much a clear toner can affect a color gamut, when it is not being applied properly. Originally, the clear toner in the imagePRESS C1+ was tinting the paper and it was observed to not be clear. This was very unimpressive and the initial results can be shown in table 1. The first item to look at is the gamut comparison, which shows the color gamut of each substrate without clear toner and compares them to the color gamut with clear toner applied. The 2-dimensional figure illustrates the change in their chromaticity, which doesn't show a big difference. The 3d figure; however, illustrates a lot more because the third dimension shows brightness. A lot of brightness was taken away as a result of this tinting, and losing brightness usually means losing contrast. Looking at the gamut volume shows how much of the gamut we actually lost. Substrate 4, which was the 60# cover, had the highest gamut loss, which was 35% of its gamut once the clear toner was applied.

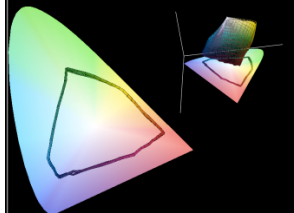
The second comparison, which was the LAB comparison also showed interesting results. First of all, placing clear toner over or under the print did not have a huge effect on the color gamut and produced low ΔE 's for each substrate. The ΔE 's for printing with and without clear toner were much worse, which supports the difference in color gamuts. A ΔE of 7.22 for substrate 3 shows that there was definitely a change in color once the clear toner was applied, which probably could be noticed with the human eye. Something like this would never be sold to a customer, so a repair technician was called in to repair the imagePRESS. It was found that the culprit was the developer related to the clear toner. After this was replaced, research could continue.

Table 2. Initial Effects of Clear Toner on Gamut.					
Substrate	Gamut Comparison Without Clear Toner vs. With Clear Toner	Gamut Volume ¹		LAB Comparison	
		Without	With	Without vs. With	Over vs. Under
Substrate 1		312,879	228,669	$\Delta E = 4.78$ $\Delta L = -0.59$ $\Delta C = -3.20$	$\Delta E = 3.18$ $\Delta L = -1.87$ $\Delta C = 1.08$
Substrate 2		322,846	255,525	$\Delta E = 4.60$ $\Delta L = -2.46$ $\Delta C = -3.01$	$\Delta E = 2.47$ $\Delta L = -1.19$ $\Delta C = 0.31$
Substrate 3		338,949	239,272	$\Delta E = 7.22$ $\Delta L = -1.65$ $\Delta C = -4.29$	$\Delta E = 1.54$ $\Delta L = -0.06$ $\Delta C = 0.17$
Substrate 4		404,957	267,681	$\Delta E = 6.86$ $\Delta L = -1.74$ $\Delta C = -3.68$	$\Delta E = 3.11$ $\Delta L = -1.88$ $\Delta C = 0.74$
Substrate 5		330,186	242,463	$\Delta E = 4.75$ $\Delta L = -1.42$ $\Delta C = -2.81$	$\Delta E = 2.15$ $\Delta L = -0.58$ $\Delta C = 1.15$

A final analysis of the clear toner indicated that it was now behaving the way it should. Using the Hammermill bond, LAB values were taken of the paper with and without clear toner (table 2). Based on these new values, the clear toner appearance was now indistinguishable from the paper, with only a slight reduction in L value.

Table 3. LAB Values of Clear Toner.		
<i>Paper</i>	<i>Old Clear Toner</i>	<i>New Clear Toner</i>
94.7, 2.1, -7	88.3, 1.8, -6.2	94.1, 2.1, -6.7

The final test left to conduct included examining the new clear toner's color gamut to see how it now behaved. The 60# cover was used for this because it had produced the highest color gamut in the previous portion of testing. Looking at the new color gamut showed very little change once the clear toner was applied and resulted in low ΔE 's. This is great because it essentially represents that the color was essentially indistinguishable once the clear toner was applied, which is the result that is wanted by users.

Table 3. Updated Effects of Clear Toner on Gamut.				
<i>Substrate</i>	<i>Gamut Comparison Without Clear Toner vs. With Clear Toner</i>	<i>Gamut Volume¹</i>		<i>LAB Comparison</i>
		<i>Without</i>	<i>With</i>	<i>Without vs. With</i>
Substrate 4		384,063	353,319	$\Delta E = 1.92$ $\Delta L = 1.09$ $\Delta C = 1.24$

Conclusion

The end result of this experiment not only showed how clear toner should affect the color gamut, but also how badly it can distort the gamut if it is not configured properly. Originally, the (not so) clear toner changed the gamut by 25 to 35 percent. After the developer was replaced that changed dramatically for the better. Another distinction that was made was whether or not printing the clear toner above or underneath the process colors made a difference. That appeared to have little effect and displayed similar results. If clear toner is a feature that will be sold to customers, then color is crucial. In some cases, such as brand identity, the clear toner cannot change the color of that brand. For uses such as security printing, the clear toner is should act as a kind of watermark and should not be easily visible.

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