

ONYX<sup>®</sup> White Paper

# Rendering Intents and Black Point Compensation

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## Introduction

The ability to apply Black Point Compensation (BPC) when applying ICC profiles was added as a new feature with the release of the X10 version of ONYX RIP products. In this document we will discuss the relationship that BPC has to ICC color rendering intents with an in-depth look at how rendering intents and BPC operate relative to the Profile Connection Space.

In ONYX RIP version X10 products, Black Point Compensation is enabled using the ICC Profile Setup dialog as seen in Figure 1.

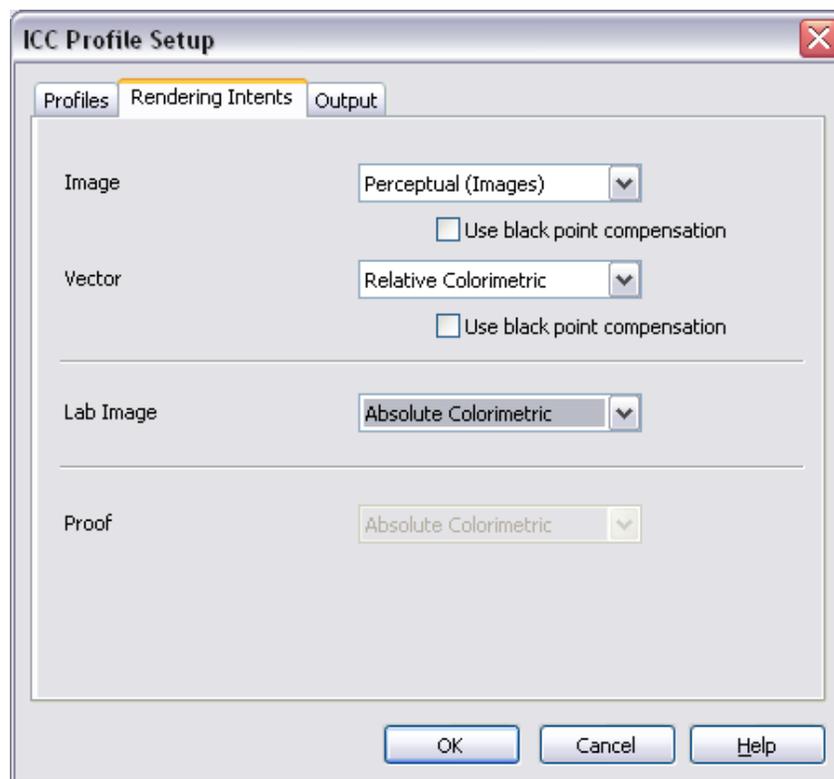


Figure 1- Profile Setup Dialog with “Black Point Compensation” controls

When using these controls you will notice that BPC can only be applied to the Relative Colorimetric Intent, the Perceptual Intent, and the Saturation Intent. It cannot be applied to the Absolute Intent, PosterColor Intent or to Lab Images. These capabilities and limitations are better understood with a more in-depth understanding of Black Point Compensation. However, to understand BPC we first need to have a review of what is happening when we connect profiles and how it relates to Profile Connection Space addressing.

## Profile Connection Space Addressing

When an input and output profiles are connected together they meet at what is known as the Profile Connection Space (PCS) which is defined by three dimensions, usually the  $L^*$ ,  $a^*$  and  $b^*$  dimensions of the CIELAB color space.

**Note:** some profiles use the CIEXYZ color space, but since there is a direct mapping to/from CIELAB, these color spaces can both equally define the PCS.

When connecting two profiles together, the input profile maps the input device color combination values to PCS addresses, and the output profile maps from PCS addresses to output device color combination values. The PCS address (or value) is used to make the connection. To better understand this connection, consider the following analogy in which post office boxes are used to deliver mail. An input profile is akin to a mailman delivering mail to a post office box. An output profile is akin to individuals getting their mail from their post office box. In this case the PO box number for a profile is equivalent to the PCS address. PO boxes can be changed or reassigned in order to account for a variety of different conditions (like new mail customers, different box sizes, etc).

One important point to remember about the PCS is that though it is based on measurement data, the data in an ICC profile for various rendering intents does not need to represent actual measured colors. In some cases the PCS values can represent desired or alternate colors. In such cases, when PCS color values (or address) differ from physical measurements associated with the actual device values, then some form of “Color Rendering” has occurred.

## Black Point Compensation

Black Point Compensation was initially developed by Adobe® to account for non-interoperability of Version 2 ICC profiles. The reason for doing this is that the black point was not well specified for the V2 perceptual intent and V2 ICC profiles from different vendors often were not interoperable. Black point compensation involves first determining CIE XYZ black points from the profiles’ transform data, and then adjusting all PCS addresses so that the XYZ values of the black points align. This is conceptually similar to the adjustment of the white point for the relative colorimetric intent.

## PCS Rendering

For the following Rendering Intent / Black Point Compensation choices a brief description and examples will be presented.

## Absolute Colorimetric Rendering Intent

The absolute colorimetric rendering intent is the only path in ICC color management where PCS addresses are identical to colorimetric measurement values. This means that NO changes are made to the PCS addressing. However, when different devices or media are used, you are more likely to have a mismatch between white points and black points of the connecting profiles. The left side of figure 2 depicts the addressing used when using the absolute colorimetric rendering intent with the V2 AdobeRGB1998.icc profile (wireframe) and a V4 profile created for Matte Media Print mode (solid).

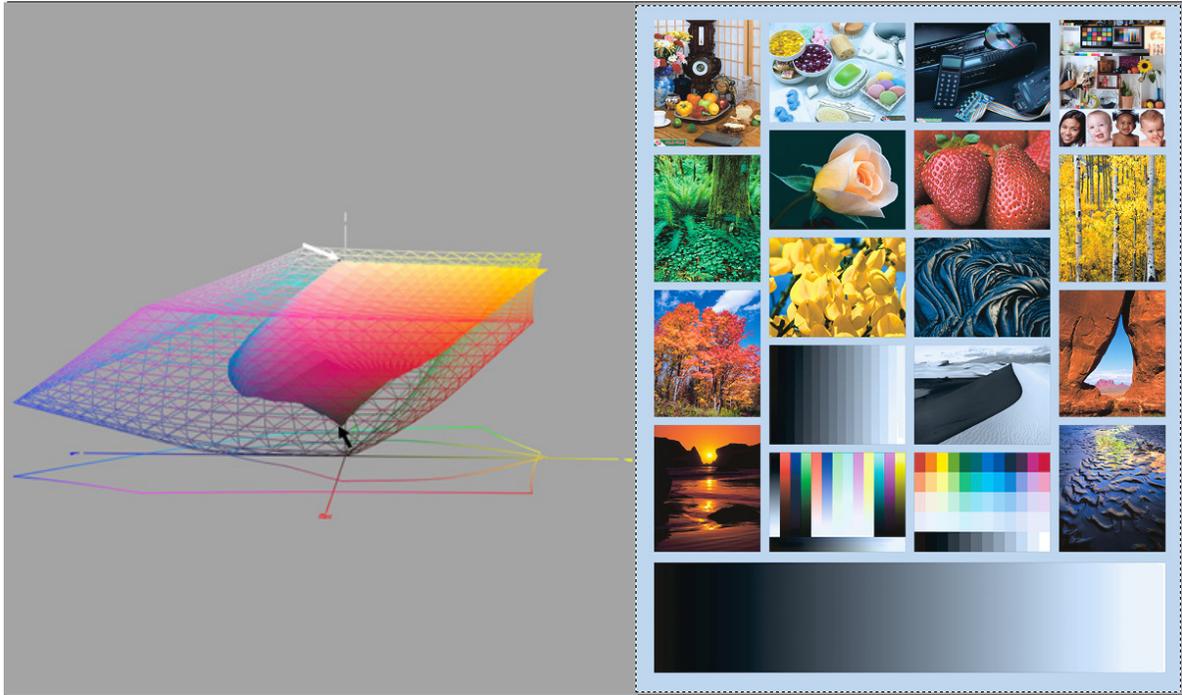


Figure 2 – PCS addressing comparison of AdobeRGB and Matte Media for Absolute Colorimetric Rendering Intent (left), results applied to RGB image (right)

Notice that in this case there is no alignment between the white and black points of the two profiles. The white and black arrows show the difference between the white and black points. Because of this mis-alignment the color balance will be bluish (since the input profile has a bluer white point relative to the output profile), and gamut mapping will be performed resulting in clipping/posterization in the highlights and shadows. These features come out in the sample image with these profiles applied in the right side of Figure 2.

**Note:** Because black point compensation involves a change in PCS addressing and the Absolute Rendering intent by definition has no change to PCS addressing, it makes sense that BPC cannot be applied to the Absolute Rendering Intent.

## Relative Colorimetric Rendering Intent

The principle of chromatic adaptation of the Human Visual System assumes that the lightest point appears “white” even if it has some absolute chroma. The relative colorimetric rendering intent adjusts the addressing of the PCS so that the white points are identical to a D50 illuminant white point. However, when different devices or media are used, you are likely to have a mismatch between black points of the connecting profiles. The left side of Figure 3 depicts the addressing used when using the relative colorimetric rendering intent with the V2 AdobeRGB1998.icc

profile (wireframe) and a V4 profile created for Matte Media Print mode (solid).

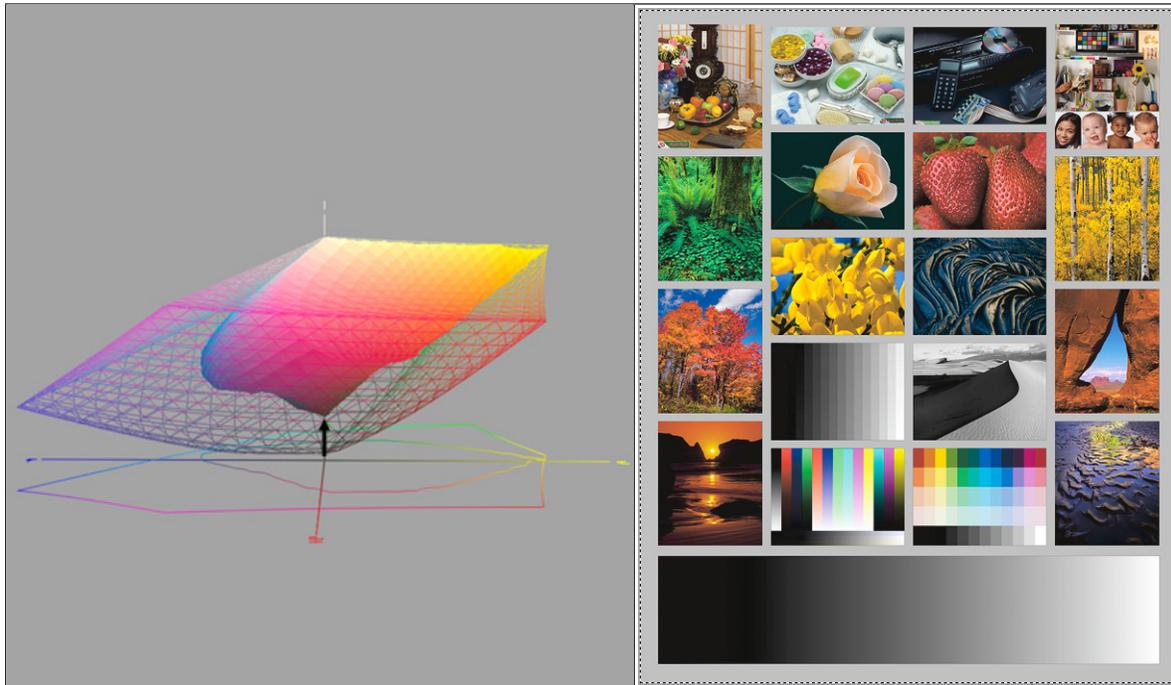


Figure 3 – PCS addressing comparison of AdobeRGB and Matte Media for Relative Colorimetric Rendering Intent (left), results applied to RGB image (right)

Notice that in this case the PCS addressing has been adjusted so that there is an alignment of the white points, however, there is no alignment between the black points. The black arrow shows the difference between the black points. The alignment of the white point results in a better color balance, however the mis-alignment of the black point results in gamut mapping of the shadows resulting in clipping/posterization of the shadows. These features come out in the sample image with these profiles applied in the right side of Figure 3. This addressing change also resulted in the input profile fully utilizing the yellow colors of the output profile (which did not occur with the absolute rendering intent).

**Technical Note:** Since matching white points is such a desirable feature, the absolute colorimetric intent is actually implemented as a PCS adjustment of the relative colorimetric intent.

## Relative Colorimetric Rendering Intent with BPC

The basic principle behind black point compensation is to perform a similar transform with the black point that is performed on the white point with the relative colorimetric rendering intent. In this case the PCS addressing is adjusted so that both the white points and black points align. This can result in an increase of the gamut addressing range when a large shift of the black point occurs. The left side of figure 4 depicts the PCS addressing of the relative colorimetric rendering intent using black point compensation with the V2 AdobeRGB1998.icc profile (wireframe) and a V4 profile created for a Matte Media Print mode (solid).

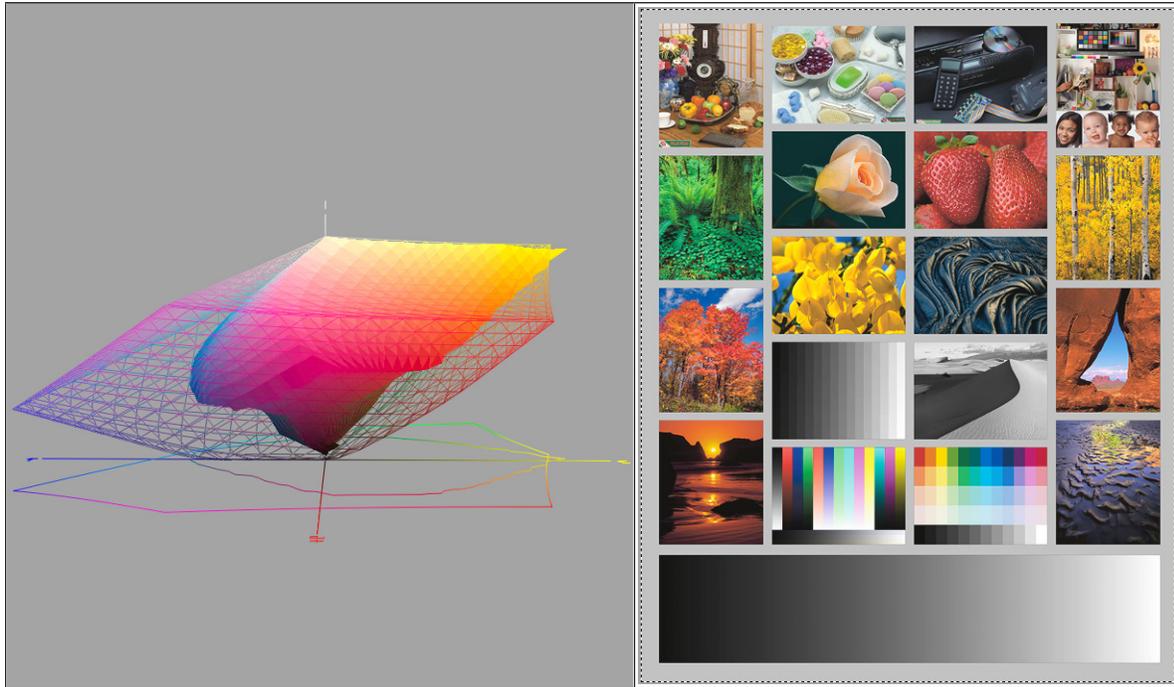


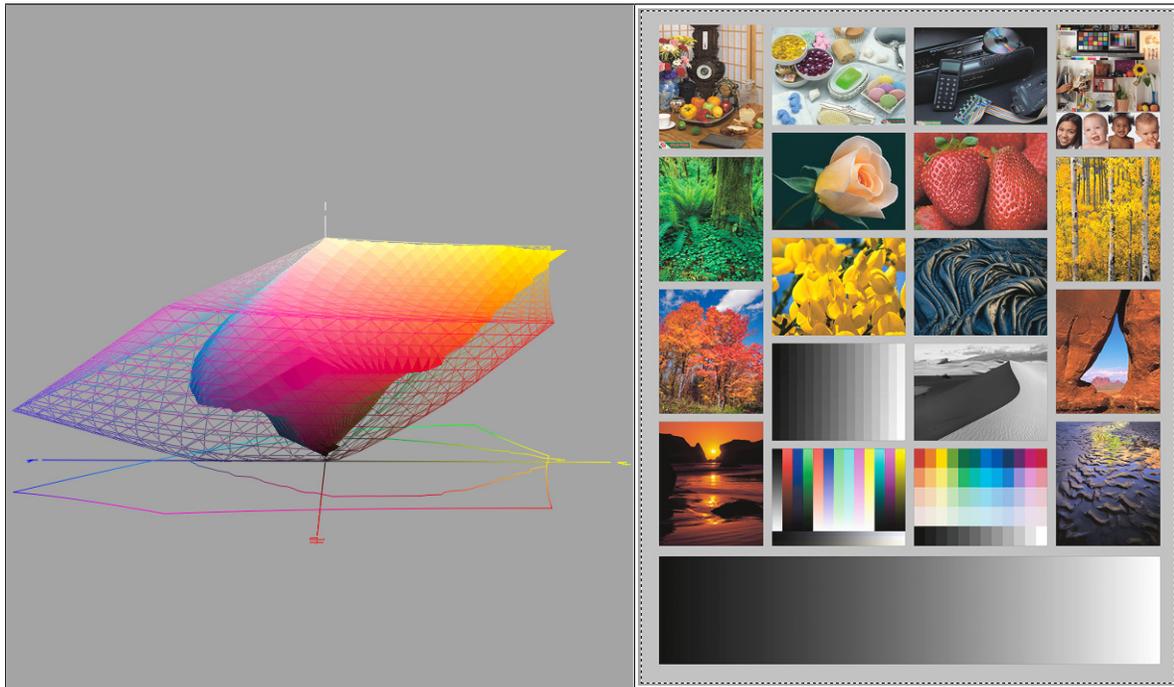
Figure 4 – PCS addressing comparison of AdobeRGB and Matte Media for Relative Colorimetric Rendering Intent with BPC (left), results applied to RGB image (right)

Notice that in this case the PCS addressing has been adjusted so that there is an alignment of both white and black points. The print gamut addressing was slightly enlarged in the process (with some inability to address the full range or the output profile's yellow region). In this case there is correct color balance and the tone scale does not have significant posterization in the shadows. These features come out in the sample image with these profiles applied, as seen in the right side of Figure 4.

This results in a pseudo-perceptual intent with rendering most similar to the perceptual rendering intent with the difference being mostly in the tone mapping and gamut mapping strategies.

## V4 Perceptual Rendering Intent

The Version 4 profile specification provided a much clearer definition of the perceptual PCS black point ( $L^* \approx 3$ ) thus overcoming interoperability failures of the V2 Perceptual Intent. With the fixed black point of the V4 perceptual PCS the profile creation vendor is required to adjust all PCS addressing so that the black point matches the V4 perceptual intent black point (thus performing a black point compensation to the data stored in the profile). When V4 and V2 profiles are mixed the black point of the V2 profile is assumed to be  $L^*=0$  which is adjusted to match the V4 black point. Since most V2 RGB input profiles make this assumption, this results in a fairly close match when combining them. The left side of Figure 5 depicts the PCS addressing of the perceptual rendering intent with the V2 AdobeRGB1998.icc profile (wireframe) and a V4 profile created for Matte Media Print mode (solid).



*Figure 5 – PCS addressing comparison of AdobeRGB and Matte Media for Relative Colorimetric Rendering Intent with BPC (left), results applied to RGB image (right)*

Notice that in this case the PCS addressing of the output profile has been adjusted so that there is a close alignment of both white and black points. The print gamut addressing was slightly enlarged in the process (with some inability to address the full range or the output profile's yellow region). In this case there is a correct color balance and the tone scale does not have significant posterization. These features come out in the sample image with these profiles applied, as seen in the right side of Figure 5. (Notice how similar the gamut addressing shape is to Relative Colorimetric Intent with BPC).

**Note:** The perceptual intent is the recommended rendering intent for image processing in ONYX RIP products.

### Perceptual Rendering Intent with BPC

Black point compensation can also be used with the Perceptual Rendering Intent. It is most helpful when V2 profiles are being used, as this can account for differences in the black points of the profiles. Applying BPC with V4 profiles will result in much smaller differences because V4 profiles already have a black point compensation applied. The left side of Figure 6 depicts the PCS addressing of the perceptual rendering intent using black point compensation with the V2 AdobeRGB1998.icc profile (wireframe) and a V4 profile created for Matte Media Print mode (solid).

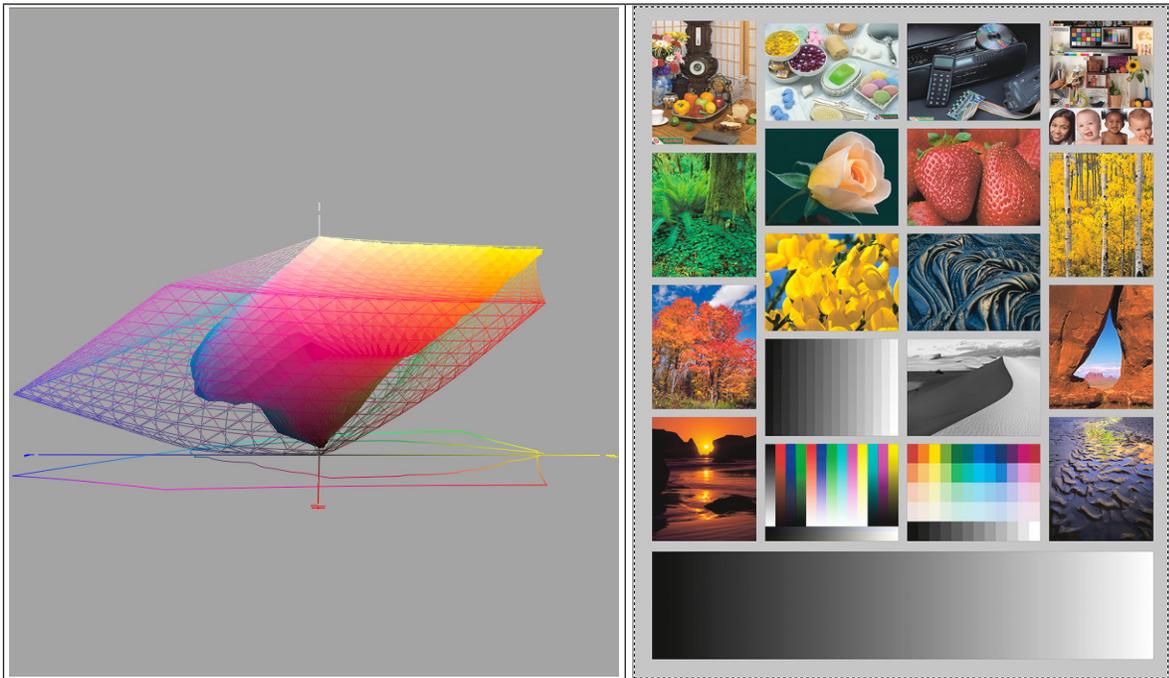


Figure 6 – PCS addressing comparison of AdobeRGB and Matte Media for Relative Colorimetric Rendering Intent with BPC (left), results applied to RGB image (right)

Notice how the changes are minimal over the perceptual intent without BPC. The black point of the V2 profile is adjusted relative to the output profile. Only slight differences in the output will appear. In this case there is also a correct color balance and the tone scale does not have significant posterization. These features come out in the sample image with these profiles applied, as seen in the right side of Figure 6.

**Note:** Since the release of the V4 ICC profile specification many V2 profiles are created using V4 assumptions for the black point. In this case there are fewer interoperability issues with V2 profiles, and the differences when applying BPC will not be as dramatic.

## Other Rendering Intents

The Saturation Rendering Intent has no requirements for the black point and is therefore subject to the same issues that the V2 perceptual intent had. As such, applying Black Point Compensation to the Saturation rendering intent may improve interoperability for profiles that have different black points.

The PosterColor Rendering Intent is an ONYX proprietary rendering intent implemented using smart CMM processing. One key feature of this processing is that the black points of the input and output profiles are aligned (as well as providing an alignment of the highly chromatic colors for each hue). Since BPC is always performed for the PosterColor rendering intent, the BPC controls are disabled.

When applying profiles to an L.A.B. image, only the output profile is applied. Since BPC involves aligning the black points of input and output profiles and there is no input profile to align to, it doesn't make sense to have a BPC option for Lab Images.

## Conclusions

The new black point compensation feature in X10 offers new opportunities for better and more predictable output. From this discussion the following points and tips can be noted:

- The Absolute Colorimetric rendering intent is the only rendering intent that has NO PCS re-addressing.
- Black Point Compensation re-maps the PCS addressing of black points of profiles to match one another.
- BPC cannot be applied to the Absolute Colorimetric rendering intent.
- BPC only makes sense when you are connecting two profiles (input & output).
- Relative Colorimetric with BPC acts as an alternative to the Perceptual intent potentially providing a different tone mapping and gamut mapping. Personal preference will have to determine when it makes sense to use Relative Colorimetric with BPC or Perceptual.
- Applying Perceptual with BPC to V2 profiles may result in much more predictable/desirable behavior depending upon the assumptions made by the V2 profile constructor.
- Applying Perceptual with BPC to V4 profiles may not result in much of a change since V4 perceptual rendering is already required to perform black point alignment.

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### **ONYX Graphics Inc.**

6915 S. High Tech Drive  
Salt Lake City, UT 84047  
Phone: 801.568.9900  
Toll Free: 800.828.0723  
[www.onyxgfx.com](http://www.onyxgfx.com)

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