

# PDF Blend Modes: Addendum

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This is an addendum to the *PDF Reference*, fifth edition, version 1.6, containing additional information about the blend modes for PDF transparency. The information is added to Section 7.2.4, “Blend Mode,” which is provided here in its entirety.

This section now contains actual formulas for all of the blend modes, some of which previously only described the appearance of the results.

*Note: The behavior of the blend modes themselves has not changed. All that this note is providing is more complete documentation of their behavior.*

## 7.2.4 Blend Mode

In principle, the blend function  $B(C_b, C_s)$ , used in the compositing formula to customize the blending operation, could be any function of the backdrop and source colors that yields another color,  $C_r$ , for the result. PDF defines a standard set of named blend functions, or *blend modes*, listed in Tables 7.1 and 7.2. Plates 18 and 19 illustrate the resulting visual effects for *RGB* and *CMYK* colors, respectively.

A blend mode is termed *separable* if each component of the result color is completely determined by the corresponding components of the constituent backdrop and source colors—that is, if the blend mode function  $B$  is applied separately to each set of corresponding components:

$$c_r = B(c_b, c_s)$$

where the lowercase variables  $c_r$ ,  $c_b$ , and  $c_s$  denote corresponding components of the colors  $C_r$ ,  $C_b$ , and  $C_s$ , expressed in additive form. (Theoretically, a blend

mode could have a different function for each color component and still be separable; however, none of the standard PDF blend modes have this property.) A separable blend mode can be used with any color space, since it applies independently to any number of components. Only separable blend modes can be used for blending spot colors.

Table 7.1 lists the standard separable blend modes available in PDF.

**TABLE 7.1 Standard separable blend modes**

| NAME            | RESULT   |
|-----------------|--|
| <b>Normal</b>   | Selects the source color, ignoring the backdrop:<br>$B(c_b, c_s) = c_s$  |
| <b>Multiply</b> | Multiplies the backdrop and source color values:<br>$B(c_b, c_s) = c_b \times c_s$ <p>The result color is always at least as dark as either of the two constituent colors. Multiplying any color with black produces black; multiplying with white leaves the original color unchanged. Painting successive overlapping objects with a color other than black or white produces progressively darker colors.</p>   |
| <b>Screen</b>   | Multiplies the complements of the backdrop and source color values, then complements the result:<br>$\begin{aligned} B(c_b, c_s) &= 1 - [(1 - c_b) \times (1 - c_s)] \\ &= c_b + c_s - (c_b \times c_s) \end{aligned}$ <p>The result color is always at least as light as either of the two constituent colors. Screening any color with white produces white; screening with black leaves the original color unchanged. The effect is similar to projecting multiple photographic slides simultaneously onto a single screen.</p> |
| <b>Overlay</b>  | Multiplies or screens the colors, depending on the backdrop color value. Source colors overlay the backdrop while preserving its highlights and shadows. The backdrop color is not replaced but is mixed with the source color to reflect the lightness or darkness of the backdrop.<br>$B(c_b, c_s) = \text{HardLight}(c_s, c_b)$   |

| NAME              | RESULT   |
|-------------------|--|
| <b>Darken</b>     | <p>Selects the darker of the backdrop and source colors:</p> $B(c_b, c_s) = \min(c_b, c_s)$ <p>The backdrop is replaced with the source where the source is darker; otherwise, it is left unchanged.</p>   |
| <b>Lighten</b>    | <p>Selects the lighter of the backdrop and source colors:</p> $B(c_b, c_s) = \max(c_b, c_s)$ <p>The backdrop is replaced with the source where the source is lighter; otherwise, it is left unchanged.</p>   |
| <b>ColorDodge</b> | <p>Brightens the backdrop color to reflect the source color. Painting with black produces no changes.</p> $B(c_b, c_s) = \begin{cases} \min(1, c_b / (1 - c_s)) & \text{if } c_s < 1 \\ 1 & \text{if } c_s = 1 \end{cases}$  |
| <b>ColorBurn</b>  | <p>Darkens the backdrop color to reflect the source color. Painting with white produces no change.</p> $B(c_b, c_s) = \begin{cases} 1 - \min(1, (1 - c_b) / c_s) & \text{if } c_s > 0 \\ 0 & \text{if } c_s = 0 \end{cases}$   |
| <b>HardLight</b>  | <p>Multiplies or screens the colors, depending on the source color value. The effect is similar to shining a harsh spotlight on the backdrop.</p> $B(c_b, c_s) = \begin{cases} \text{Multiply}(c_b, 2 \times c_s) & \text{if } c_s \leq 0.5 \\ \text{Screen}(c_b, 2 \times c_s - 1) & \text{if } c_s > 0.5 \end{cases}$  |
| <b>SoftLight</b>  | <p>Darkens or lightens the colors, depending on the source color value. The effect is similar to shining a diffused spotlight on the backdrop.</p> $B(c_b, c_s) = \begin{cases} c_b - (1 - 2 \times c_s) \times c_b \times (1 - c_b) & \text{if } c_s \leq 0.5 \\ c_b + (2 \times c_s - 1) \times (D(c_b) - c_b) & \text{if } c_s > 0.5 \end{cases}$ <p>where <math>D(x) = \begin{cases} ((16 \times x - 12) \times x + 4) \times x &amp; \text{if } x \leq 0.25 \\ \sqrt{x} &amp; \text{if } x &gt; 0.25 \end{cases}</math></p> |

| NAME              | RESULT   |
|-------------------|--|
| <b>Difference</b> | Subtracts the darker of the two constituent colors from the lighter color:<br>$B(c_b, c_s) =  c_b - c_s $ Painting with white inverts the backdrop color; painting with black produces no change.                                      |
| <b>Exclusion</b>  | Produces an effect similar to that of the <b>Difference</b> mode but lower in contrast. Painting with white inverts the backdrop color; painting with black produces no change.<br>$B(c_b, c_s) = c_b + c_s - 2 \times c_b \times c_s$ |

Table 7.2 lists the standard nonseparable blend modes. Since the nonseparable blend modes consider all color components in combination, their computation depends on the blending color space in which the components are interpreted. They may be applied to all multiple-component color spaces that are allowed as blending color spaces (see Section 7.2.3, “Blending Color Space”).

All of these blend modes conceptually entail the following steps:

1. Convert the backdrop and source colors from the blending color space to an intermediate *HSL* (hue-saturation-luminosity) representation.
2. Create a new color from some combination of hue, saturation, and luminosity components selected from the backdrop and source colors.
3. Convert the result back to the original (blending) color space.

However, the formulas given below do not actually perform these conversions. Instead, they start with whichever color (backdrop or source) is providing the hue for the result; then they adjust this color to have the proper saturation and luminosity.

The nonseparable blend mode formulas make use of several auxiliary functions. These functions operate on colors that are assumed to have red, green, and blue components. (Blending of *CMYK* color spaces requires special treatment, as described below.)

$$\text{Lum}(C) = 0.3 \times C_{\text{red}} + 0.59 \times C_{\text{green}} + 0.11 \times C_{\text{blue}}$$

SetLum( $C, l$ )

```

let  $d = l - \text{Lum}(C)$ 
 $C_{\text{red}} = C_{\text{red}} + d$ 
 $C_{\text{green}} = C_{\text{green}} + d$ 
 $C_{\text{blue}} = C_{\text{blue}} + d$ 
return ClipColor( $C$ )

```

ClipColor( $C$ )

```

let  $l = \text{Lum}(C)$ 
let  $n = \min(C_{\text{red}}, C_{\text{green}}, C_{\text{blue}})$ 
let  $x = \max(C_{\text{red}}, C_{\text{green}}, C_{\text{blue}})$ 
if  $n < 0.0$ 
   $C_{\text{red}} = l + (((C_{\text{red}} - l) \times l) / (l - n))$ 
   $C_{\text{green}} = l + (((C_{\text{green}} - l) \times l) / (l - n))$ 
   $C_{\text{blue}} = l + (((C_{\text{blue}} - l) \times l) / (l - n))$ 
if  $x > 1.0$ 
   $C_{\text{red}} = l + (((C_{\text{red}} - l) \times (1 - l)) / (x - l))$ 
   $C_{\text{green}} = l + (((C_{\text{green}} - l) \times (1 - l)) / (x - l))$ 
   $C_{\text{blue}} = l + (((C_{\text{blue}} - l) \times (1 - l)) / (x - l))$ 
return  $C$ 

```

$$\text{Sat}(C) = \max(C_{\text{red}}, C_{\text{green}}, C_{\text{blue}}) - \min(C_{\text{red}}, C_{\text{green}}, C_{\text{blue}})$$

In the following function, the subscripts *min*, *mid*, and *max* refer to the color components having the minimum, middle, and maximum values upon entry to the function.

SetSat( $C, s$ )

```

if  $C_{\text{max}} > C_{\text{min}}$ 
   $C_{\text{mid}} = (((C_{\text{mid}} - C_{\text{min}}) \times s) / (C_{\text{max}} - C_{\text{min}}))$ 
   $C_{\text{max}} = s$ 
else
   $C_{\text{mid}} = C_{\text{max}} = 0.0$ 
 $C_{\text{min}} = 0.0$ 
return  $C$ 

```

TABLE 7.2 Standard nonseparable blend modes

| NAME              | RESULT  |
|-------------------|---|
| <b>Hue</b>        | Creates a color with the hue of the source color and the saturation and luminosity of the backdrop color.<br>$B(C_b, C_s) = \text{SetLum}(\text{SetSat}(C_s, \text{Sat}(C_b)), \text{Lum}(C_b))$  |
| <b>Saturation</b> | Creates a color with the saturation of the source color and the hue and luminosity of the backdrop color. Painting with this mode in an area of the backdrop that is a pure gray (no saturation) produces no change.<br>$B(C_b, C_s) = \text{SetLum}(\text{SetSat}(C_b, \text{Sat}(C_s)), \text{Lum}(C_b))$ |
| <b>Color</b>      | Creates a color with the hue and saturation of the source color and the luminosity of the backdrop color. This preserves the gray levels of the backdrop and is useful for coloring monochrome images or tinting color images.<br>$B(C_b, C_s) = \text{SetLum}(C_s, \text{Lum}(C_b))$                       |
| <b>Luminosity</b> | Creates a color with the luminosity of the source color and the hue and saturation of the backdrop color. This produces an inverse effect to that of the <b>Color</b> mode.<br>$B(C_b, C_s) = \text{SetLum}(C_b, \text{Lum}(C_s))$  |

The above formulas apply to *RGB* spaces. Blending in *CMYK* spaces (including both **DeviceCMYK** and **ICCBased** calibrated *CMYK* spaces) is handled in the following way:

- The *C*, *M*, and *Y* components are converted to their complementary *R*, *G*, and *B* components in the usual way. The formulas above are applied to the *RGB* color values. The results are converted back to *C*, *M*, and *Y*.
- For the *K* component, the result is the *K* component of  $C_b$  for the **Hue**, **Saturation**, and **Color** blend modes; it is the *K* component of  $C_s$  for the **Luminosity** blend mode.

**Note:** An additional standard blend mode, **Compatible**, is a vestige of an earlier design and is no longer needed but is still recognized for the sake of compatibility. Its effect is equivalent to that of the **Normal** blend mode. See “Compatibility with Opaque Overprinting” on page 537 for further discussion.