PDF/A Competence Center

TechNote 0002: Color in PDF/A-1

The PDF/A-1 requirements related to color handling may be confusing to users and developers who are not familiar with color management concepts and ICC profiles. This TechNote describes the affected objects in PDF, details the requirements of PDF/A-1 with respect to color handling, and provides recommendations for color strategies in common situations.

Contrary to popular belief, specifying an RGB value for, say, black does not accurately specify any color, but merely instructs a particular device to render the darkest possible color – which will be different on different devices. Similarly, 50% red in RGB may look like a clearly specified color, but it fails to define the red base color to use. Again, the visual results will be different on multiple output devices. These problems can be solved by using device-independent color specifications.

Since PDF/A-1 is targeted at long-time preservation of the document's visual appearance, device-independent color specification methods are required. PDF/A-1 makes use of several PDF concepts for specifying color without any dependency on actual output devices.

1 PDF Color Concepts

1.1 Color Spaces in PDF

PDF supports various color spaces which can be grouped as follows:

- Device color spaces refer to a specific output technology, and cannot be used to specify color values such that colors are reproducible in a predictable way across a range of output devices: *DeviceGray*, *DeviceRGB*, *DeviceCMYK.*
- CIE-based color spaces specify colors in a way which is related to the human visual perception; they are inherently capable of specifying colors which can be reliably reproduced on multiple output devices: *CalGray*, *CalRGB*, *Lab*, *ICCBased.* These are also referred to as device-independent color spaces.
- Special color spaces:
  Separation and *DeviceN* require an alternate color space from one of the previous two groups. The alternate color space allows the PDF consumer to simulate the color on devices which do not support the specified Separation or DeviceN color space directly.
  The *Indexed* color space requires a base color space, and only serves as a compact notation for the base color space.
  The *Pattern* color space is used to create repeating figures (tiling pattern) or smooth gradients (shading patterns). It can work with one or more of the other color spaces.

1.2 Sources of Color

It is important to keep in mind where color spaces can play a role in PDF. Color in PDF may be related to the following types of objects:

- Raster images, i.e. Image XObjects or inline images
- Text and vector objects in content streams; PDF supports the following uses of content streams: page contents, Form XObjects, appearance streams for annotations (including form fields), glyph descriptions for a Type 3 font, and patterns.
- Decoration of interactive elements, e.g. annotation borders
- Thumbnail images, i.e. the Thumb entry in a page dictionary
- Shading patterns
- Transparency groups (but transparency isn’t permitted anyway in PDF/A-1)
- Bookmarks

Note **Although bookmarks can be colorized with the /C entry in an outline item dictionary, they are considered interactive elements that do not need to be color managed. In other words, all color-related requirements discussed in this TechNote do not apply to bookmarks.**

1.3 Default Color Spaces

Default color spaces provide a way to systematically remap device-specific colors to device-independent colors. In order to achieve this, one of the entries DefaultGray, DefaultRGB, or DefaultCMYK must be present in the appropriate resource dictionary. A default color space may contain any color space other than Lab, Indexed, or Pattern. The default color space will be used instead of the original DeviceGray, DeviceRGB, or DeviceCMYK color space, and must be compatible with it (same number of components).

The PDF 1.4 reference doesn't explicitly specify whether default color spaces apply to the colors used in annotations (e.g. border colors). Annotation colors should therefore be treated as device-dependent colors even if the page specifies a device-independent default color space.

1.4 ICC Profiles

ICC profiles are a file format which can be used to describe the color characteristics of a particular device. The ICC specification [4] explains that "device profiles provide color management systems with the information necessary to convert color data between native device color spaces and device independent color spaces". The ICC specification classifies color devices according to their use as input devices (e.g. scanners, digital cameras; device class signature "scnr"), display devices (e.g. monitors; device class signature "mntr"), or output devices (e.g. printers; device class signature "prtr").

ICC profiles have been standardized by the International Color Consortium ICC, and form the basis of modern color management. ICC profile support ranges from operating systems to applications as well as input and output devices. The ICC file format and color management framework has also been published as ISO 15076 [8]).

An ICC profile often does not describe a specific device, but rather a class of devices (or printing conditions in the case of output devices). However, ICC profiles can be created for specific devices if high quality in color reproduction must be achieved.

In PDF ICC profiles are mainly used to define ICCBased color spaces or to specify the destination profile in an output intent (see next section). ICC profiles can also be used to specify default color spaces to map device-dependent colors to

device-independent colors. All these uses of ICC profiles are supported in PDF/A-1.

An ICC profile which is used to define an ICCBased color space must include the "toCIE" profile information ("AToB" in ICC terminology); the "fromCIE" information ("BToA") will be ignored if present.

ICC profiles include major and minor version numbers which reflect the version of the ICC specification to which the profile conforms. According to the PDF reference for PDF 1.3 and later versions, only specific major/minor ICC profile versions are supported by a particular PDF version. For example, according to the PDF 1.4 reference only profiles based on ICC specification ICC.1:1998-09 and its addendum ICC.1A:1999-04 (internal profile version 2.2) are supported. However, this caused problems for users as profiling software moved to newer ICC versions. Since the ICC specification mandates that changes in the minor version number must never introduce any incompatible changes, industry experts from the PDF/A, PDF/X, and color communities agreed on the following relaxed ICC versioning scheme for PDF:

- PDF 1.4 and below accept ICC major version 2 (any minor version).
- PDF 1.5 and above accept ICC major version 4 or below (any minor version).

On this basis PDF/A-1 documents can use all version 2.x ICC profiles, regardless of the minor version.

PDF up to 1.7 supports ICC profiles in the color spaces Grayscale, RGB, CMYK, and Lab.

ICC profiles can be embedded in all common raster graphics formats. Most scanners will include an ICC profile in the generated image data ("image tagging"). If the profile is kept with the image data when creating PDF from the image, the result will be a device-independent ICCBased color space. If the profile is dropped in the process, the result will be a device-dependent color space unless a "best guess" profile is attached, e.g. the sRGB profile discussed below.

1.5 Output Intents

The output intent in a PDF document describes the intended class of output devices or the intended printing condition. In PDF 1.4 output intents can be specified by an identifying name, or by means of an embedded ICC destination profile (DestOutputProfile).

An ICC profile which is used as a destination profile in an output intent must include the "toCIE" profile information ("AToB") and the "fromCIE" information ("BToA"). This means that only display device (device class "mntr") and output device (device class "prtr") profiles are allowed. Input device profiles (device

class “scnr”) and color space conversion profiles (signature “spac”) are not allowed. This condition is not explicitly stated in the PDF Reference, though.

The PDF consumer will use the output intent to convert all device-dependent colors to device-independent colors. Applying standard ICC conversion rules these will in turn be adjusted to produce the colors on the selected device (e.g. monitor or printer) using the device’s ICC profile.

A PDF document may contain multiple output intents, where each intent has a unique subtype. At the time of publication subtypes for PDF/X and PDF/A-1 have been defined, but there may be subtypes for other purposes as well.

An OutputConditionIdentifier is required for each output intent regardless of its subtype; this is a string which identifies the intended output device or production condition.

2 Output Intents in PDF/A-1

2.1 Types of Output Intents

In PDF/A-1 device-independent color specification can be achieved by the following methods (or a combination of those):

- Colors are directly specified in one or more device-independent color spaces;
- Device-independent colors can be specified indirectly via default color spaces.
- The target output condition for viewing or printing is characterized by means of the destination profile in the output intent (which must have the subtype GTS_PDFA1). Regular ICC profiles are used as the destination profile in such output intents.

Subject to the types of color spaces used in the document, an output intent may or may not be required. The following situations are possible in PDF/A-1 with respect to the output intent:

- No output intent is present
- Embedded grayscale profile (color space signature "GRAY") as destination profile in the output intent
- Embedded RGB profile (color space signature "RGB ") as destination profile in the output intent
- Embedded CMYK profile (color space signature "CMYK") as destination profile in the output intent

2.2 Comparison of PDF/A and PDF/X Output Intents

While the general concept of using output intents in PDF/A-1 is similar to the PDF/X family of standards for the exchange of PDF documents in the graphic arts industry, the following differences between PDF/A-1 and PDF/X-3 (or PDF/X-1a which has the same output intent requirements as PDF/X-3) should be noted:

- PDF/X-1a and PDF/X-3 always require an output intent, while PDF/A-1 documents do not necessarily need an output intent (if all colors are specified in device-independent color spaces).
- While PDF/X-1a and PDF/X-3 allow references to a *standard printing condition* by name (without embedding any destination profile), PDF/A-1 always requires a destination profile to be embedded in a PDF/A-1 output intent (if

an output intent is present at all). No references to external destination profiles are allowed to avoid any dependencies.

- While PDF/X-1a and PDF/X-3 allow only output device profiles (device class "prtr") as destination profile in the output intent, PDF/A-1 supports all ICC profile types which are permitted by the PDF 1.4 reference. In particular, monitor profiles are allowed in PDF/A-1, but not in PDF/X-1a or PDF/X-3.

A PDF/A-1 document can at the same time conform to PDF/X-1a or PDF/X-3. While PDF/X-1a and PDF/X-3 require an output intent via an embedded destination profile or a reference to a standard output condition, PDF/A-1 does not support the use of named standard output conditions. Therefore, such combined documents may refer to a standard output condition in the PDF/X output intent, and an embedded destination profile in the PDF/A-1 output intent. However, if both the PDF/X and PDF/A-1 output intents are specified by a destination profile, both profiles must be described by the same ICC profile stream object in the PDF. PDF/A-1 does not allow embedding of two different destination profiles for the PDF/X and PDF/A-1 output intents.

3 Where can I get ICC Profiles?

Although software is available which can be used to create ICC profiles for a given device, only few PDF/A-1 users and developers will be in a position to create custom ICC profiles appropriate for the intended use of their documents. (Creating custom profiles may only be relevant when converting analog content to PDF, e.g. with scanners or diagnostic devices.) Before discussing color strategies for PDF/A-1 we'd like to mention some sources of freely available and high-quality ICC profiles.

Note **The ICC profiles listed below are available for free download. However, the PDF/A Competence Center advises all implementors to obtain any required redistribution rights from the respective licensor if they intend to include these profiles in their products.**

3.1 sRGB ICC Profile

The sRGB ("standard RGB") color space has been jointly developed by HP and Microsoft in order to provide an easy color management approach for common computer graphics and digital photography scenarios. It is especially targeted at common RGB monitors and digital cameras, and widely supported by other vendors. sRGB has also been published by several standards organizations, including W3C and ISO/IEC (61966-2-1) [5], [7]. Many devices, including scanners, cameras, monitors and printers support the sRGB color space without any additional configuration. This makes the sRGB color space a good basis for color management in situations where the effort for creating custom ICC profiles is not justified.

ICC profiles for the sRGB color space are freely available from several sources (see Bibliography).

3.2 ECI ICC Profiles

The European Color Initiative (ECI) is "a group of experts which is dedicated to advancing media-neutral color data-processing in digital publishing systems". ECI has published various materials related to color management issues, and has produced a number of high-quality ICC color profiles which are available for free download [9]. These ICC profiles are mainly targeted at offset and gravure printing, but also include the eciRGB profile which supports a wider gamut (range of colors) than sRGB. However, eciRGB should not be used as a best guess profile for tagging any image source data or as the destination profile in an output intent since it does not describe any actual device, but rather serves as a working color space (which is encoded as a monitor profile). RGB contents of unknown origin are usually best described by sRGB.

3.3 Adobe ICC Profiles

Adobe makes available RGB and CMYK profiles for free download [10]. The RGB profiles include Adobe RGB which offers some advantages over sRGB. While sRGB is common in consumer products, Adobe RGB is used e.g. in high-end professional cameras. However, Adobe RGB should not be used as a best guess profile for tagging any image source data or as the destination profile in an output intent since it does not describe any actual device, but rather serves as a working color space (which is encoded as a monitor profile). RGB contents of unknown origin are usually best described by sRGB.

The CMYK profiles cover common international printing conditions, such as SWOP (US), ISO Coated Fogra 27 (Europe), and Japan Web Coated.

3.4 Ifra Profiles for Newspaper Publishing

Ifra is "the world's leading association for newspaper and media publishing". Ifra is actively involved in the standardization of newspaper printing processes, and publishes grayscale and CMYK ICC profiles [11] for newspaper printing operations on the basis of ISO 12647-3.

4 Color Strategies for PDF/A-1

4.1 Overview of Color Scenarios

The table below details which device and CIE-based color spaces can be used in a PDF/A-1 document subject to the choice of output intent. The table assumes that color mapping through default color spaces already happened, i.e. the "color spaces which can be used in the document" refer to the result of these default color space mappings.

A PDF/A-1 document may contain up to one unique PDF/A-1 output intent which must describe either a Grayscale, RGB, or CMYK color space. As detailed in the table below, an RGB output intent excludes the use of DeviceCMYK color, and vice versa (unless suitable default color spaces are present). However, DeviceGray color can be used with any type of output intent.

Special color spaces are not listed in the table; they must be treated according to the respective base or alternate color space. For example, a *Separation* color with an ICCBased alternate color space can always be used, while a Separation color with DeviceCMYK alternate color space requires a CMYK ICC profile as output intent.

	color spaces which can be used in the document:			
PDF/A-1 output intent	**Lab, CalGray, CalRGB, ICCBased**	**DeviceGray**	**DeviceRGB**	**DeviceCMYK**
none	yes	–	–	–
Grayscale ICC profile	yes	yes	–	–
RGB ICC profile, e.g. sRGB	yes	yes	yes	–
CMYK ICC profile	yes	yes	–	yes

4.2 Fully Color-managed Workflow

In a fully color-managed scenario only device-independent color spaces are used. As a consequence, an output intent is not required for PDF/A-1. In this scenario all raster images are "tagged" with appropriate ICC profiles (which can be provided by a scanner or digital camera, for example), or specified in the device-independent Lab, CalGray, or CalRGB color spaces. Text and vector graphics are also specified in a device-independent manner. For example, black text can be specified as Lab triple (0, 0, 0), as ICCBased gray value 0, or as ICCBased RGB triple (0, 0, 0).

4.3 sRGB ICC Profile as Output Intent

The easiest approach which will work in many situations is to use an RGB output intent ICC profile, since most color spaces except DeviceCMYK can be used in the document. If PDF annotations specify colors in a C or IC entry (e.g. border color for a link annotation) these colors are always specified in the DeviceRGB color space; PDF 1.4 does not support device-independent color specifications for annotations. Therefore, if the document contains colorized annotations an RGB output intent is required.

Using the sRGB ICC profile as output intent has the advantage of being compatible with a wide range of existing applications and devices. sRGB will also provide good results in situations where no information about the color characteristics of existing data is available.

4.4 Print Files in the Graphic Arts Industry

PDF documents for high-volume printing (such as magazines, newspapers, sales literature, and catalogues) are generally prepared for a particular printing condition for which an ICC profile is available. This ICC profile can, and should, be used as the output intent's destination profile when creating PDF/A-1 from these documents.

4.5 Mixed Workflows

The approaches described above can be combined. For example, some parts of the document can be described in device-independent color spaces, while an output intent is still provided since other elements in the document use the DeviceGray, DeviceRGB, or DeviceCMYK color space.

4.6 Recommendations

- If you don't feel familiar with color management or have Grayscale or RGB image data from unknown sources, use sRGB as destination profile in the PDF/A-1 output intent.
- Archive migration: if you want to convert existing scanned image data (e.g. TIFF) to PDF/A-1, attach the scanner's ICC profile to the image data. If the scanner profile is not available, sRGB can often be used as an approximation.
- If data in the DeviceCMYK color space must be included, use the "ISO coated" ICC profile provided by ECI as source profile for all CMYK data.

- Use one of the Adobe, ECI, or Ifra ICC profiles as destination profile in the PDF/A-1 output intent if you are creating PDF/A from publication print data (e.g. newspapers or magazines).

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Status of this Document

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2007-04-16 Re-released without any changes in content to fix problems in the PDF document's XMP metadata caused by two bugs in Acrobat Distiller 8

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- Updated formatting and added references to the entries in the bibliography
- Section 1.2: mention bookmarks as sources of color, and clarify that they do not need to be color managed
- Section 1.4: added explanation of relaxed version checking for ICC profiles in PDF
- Bibliography: added reference to ISO 15076-1
- Copyright and Usage: added contact info