

Extending L^AT_EX's color facilities: the **xcolor** package

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Abstract

xcolor provides easy driver-independent access to several kinds of colors, tints, shades, tones, and mixes of arbitrary colors by means of color expressions like `\color{red!50!green!20!blue}`. It allows to select a document-wide target color model and offers tools for automatic color schemes, conversion between twelve color models, alternating table row colors, color blending and masking, color separation, and color wheel calculations.

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*This package can be downloaded from CTAN/macros/latex/contrib/xcolor/. There is also an **xcolor** homepage: www.ukern.de/tex/xcolor.html. Please send error reports and suggestions for improvements to the author: xcolor@ukern.de.

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1 Introduction

1.1 Purpose of this package

The `color` package provides a powerful and stable tool for handling colors within (pdf) \LaTeX in a consistent and driver-independent way, supporting several color models (slightly less driver-independent).

Nevertheless, it is sometimes a bit clumsy to use, especially in cases where slight color variations, color mixes or color conversions are involved: this usually implies the usage of another program that calculates the necessary parameters, which are then copied into a `\definecolor` command in \LaTeX . Quite often, also a pocket calculator is involved in the treatment of issues like the following:

- My company has defined a corporate color, and the printing office tells me how expensive it is to use more than two colors in our new brochure, whereas all kinds of tints (e.g., a 75% version) of our color can be used at no extra cost. But how to access these color variations in \LaTeX ?
(Answer: `\color{CorporateColor!75}` etc.)
- My friend uses a nice color which I would like to apply in my own documents; unfortunately, it is defined in the **hsb** model which is not supported in my favorite application pdf \LaTeX . What to do now?
(Answer: just use the **hsb** definitions, `xcolor` will do the necessary calculations)
- How does a mixture of 40% *green* and 60% *yellow* look like?
(Answer: 40%  + 60%  = , e.g., `\color{green!40!yellow}`)
- And how does its complementary color look like?
(Answer: , accessible via `\color{-green!40!yellow}`)
- Now I want to mix three parts of the last color with two parts of its complement and one part of *red*. How does that look?
(Answer: $3 \times$  $+ 2 \times$  $+ 1 \times$  = , the last color being accessible via `\color{rgb:-green!40!yellow,3;green!40!yellow,2;red,1}`)
- I know that light waves of 485nm are within the visible range. But which color do they represent?
(Answer: approximately , via `\color[wave]{485}`)
- My printing office wants all color definitions in my document to be transformed into the **cmymk** model. How can I do the calculations efficiently?
(Answer: `\usepackage[cmymk]{xcolor}` or `\selectcolormodel{cmymk}`)
- I have a table with 50 rows. How can I get alternating colors for entire rows without copying 50 `\rowcolor` commands? The alternating scheme should start in the 3rd row.
(Answer: something like `\rowcolors{3}{OddColor}{EvenColor}`)

These are some of the issues solved by the `xcolor` package. Its purpose can be summarized as to maintain the characteristics of `color`, while providing additional features and flexibility with (hopefully) easy-to-use interfaces.

1.2 Color tints, shades, tones, and complements

According to [15] we define the terms

- **tint**: a color with *white* added,
- **shade**: a color with *black* added,
- **tone**: a color with *gray* added.

These are special cases of a general function $\text{mix}(C, C', p)$ which constructs a new color, consisting of p parts of color C and $1 - p$ parts of color C' , where $0 \leq p \leq 1$. Thus, we set

$$\text{tint}(C, p) := \text{mix}(C, \text{white}, p) \quad (1)$$

$$\text{shade}(C, p) := \text{mix}(C, \text{black}, p) \quad (2)$$

$$\text{tone}(C, p) := \text{mix}(C, \text{gray}, p) \quad (3)$$

where **white**, **black**, and **gray** are model-specific constants, see table 7 on page 45. Further we define the term

- **complement**: a color C^* that yields *white* if superposed with the original color C ,

knowing that there are also different concepts of complementarity in place (e.g., opposite colors on *color wheels*). See section 6.3 on page 47 for calculation details and section 1.4 for some remarks on color wheels.

1.3 Color models

A color model is a tool to describe or represent a certain set of colors in a way that is suitable for the desired target device, e.g., a screen or a printer. There are proprietary models (like Pantone or HKS) that provide finite sets of colors (often called *spot colors*), where the user has to choose from without caring about parametrisations; on the other hand, there are parameter-driven models like **gray**, **rgb**, and **cmymk**, that aim to represent large finite or even (theoretically) infinite sets of colors, built on very small subsets of base colors and rules, how to construct other colors from these base colors. For example, a large range of colors can be constructed by linear combinations of the base colors *red*, *green*, and *blue*. On the other hand, usually spot colors can only be *approximated* by parameter values in models like **cmymk** or **rgb**; the original colors are being physically mixed even dependent on the targeted kind of paper. Finally, there are certain colors like *gold* and *silver* that are hardly reproducible by any parameter-driven color model on standard ink or laser printers.

1.4 Color wheels and color harmony

There has been a long history of placing colors (hues) on wheels in order to discuss theoretical or practical color issues (e.g., Isaac Newton, Johann Wolfgang von Goethe). One reason may be that the circle itself is a natural tool to demonstrate common relationships as well as opposite properties.

Nowadays, there exists some confusion about notions, since both major areas related to color — art and graphics design on one hand, scientific color theory

on the other hand — tend to use the same words to describe color properties, however meaning sometimes very different facts! Thus, the appearance of color wheels differs as well as the meaning of concepts like ‘primary’ or ‘complementary’ colors.

Typical color wheel construction First, three *primary colors* are placed at 0° , 120° , 240° (artists often choose *red*, *yellow*, *blue*, whereas color scientists might prefer *red*, *green*, *blue*). Next, three *secondary colors* are put at 60° , 180° , 300° . Then, six *tertiary colors* may be placed in between (30° , 90° , \dots). This is why color wheels are frequently described to consist of twelve equidistant colors, although the algorithm can be repeated arbitrarily often.

Color harmonies derived from a wheel We start with an arbitrary color wheel:

- **complementary colors** have a distance of 180° on the wheel,
- **color triads** consist of three colors in 120° steps,
- **color tetrads** consist of four colors in 90° steps.

We assume now that the wheel is partitioned into $2n$ sectors of equal size:

- **split complementary colors** of a given color are the two immediate neighbours of its complementary color, characterised by the positions $\frac{n\pm 1}{2n} \cdot 360^\circ$,
- **analogous colors** to a given color are its two or four neighbours, characterised by the positions $\pm \frac{1}{2n} \cdot 360^\circ$ and $\pm \frac{2}{2n} \cdot 360^\circ$.

Given these methods to generate ‘color harmonies’, we conclude that the results depend heavily on how we constructed the wheel! Moreover, the choice of n will affect the visual results as well. Examples are shown in figure 12 on page 37.

2 The User Interface

2.1 Preparation

2.1.1 Package installation

First of all, put `xcolor.sty` and all the `.def` files to some place where (pdf)LaTeX finds them. A typical place according to the *TeX Directory Structure* (TDS) would be the directory `texmf/tex/latex/xcolor`, where `texmf` denotes the main directory of your TeX installation. Additionally, put `xcolor.pro` to a place where *dvips* finds it, typically `texmf/dvips/xcolor`. Usually, you will have to run some kind of filename database update in order to make the files known and quickly searchable to the TeX system. Then simply use `xcolor` (instead of `color`) in your document. Thus, the general command is `\usepackage[<options>]{xcolor}` in the document preamble. Table 2 on page 10 shows what has to be taken into account with respect to the package loading order.

2.1.2 Package options

In general, there are several types of options:

- options that determine the color driver as explained in [5] and [6], currently: `dvips`, `xdvi`, `dvipdf`, `dvipdfm`, `dvipdfmx`, `pdftex`, `dvipsone`, `dviwindo`, `emtex`, `dviwin`, `oztex`, `textures`, `pctexps`, `pctexwin`, `pctexhp`, `pctex32`, `truetex`, `tcidvi`, `vtex`, `xetex`,
- options that determine the target color model¹ (`natural`, `rgb`, `cmj`, `cmjk`, `hsb`, `gray`, `RGB`, `HTML`, `HSB`, `Gray`) or disable colored output (`monochrome`),
- options that control whether and how certain sets of predefined colors are being loaded: `dvipsnames`, `dvipsnames*`, `svgnames`, `svgnames*`, `x11names`, `x11names*`,
- options that determine which other packages are to be loaded (`table`, `fixpdxftex`, `pst`²) or supported (`hyperref`),
- options that determine the behaviour of other commands: `prologue`, `kernelbbox`, `xcdraw`, `noxcdraw`, `showerrors`, `hideerrors`,
- obsolete options: `override`, `usenames`, `nodvipsnames`.

All available package options (except driver selection and obsolete options) are listed in table 1 on page 9. In order to facilitate the co-operation with the `hyperref` package, there is a command `\GetGinDriver`³ that grabs the driver actually used and puts it into the command `\GinDriver`. The latter can then be used within `hyperref` (or other packages), see the code example on page 11. If there is no corresponding `hyperref` option, `hypertex` will be taken as default.

Warning: there is a substantial difference between `xcolor` and `color` regarding how the `dvips` option is being handled. The `color` package implicitly invokes

¹Section 2.2.3 on page 11 explains how this setting can be overridden at any point in a document.

²This option will soon become obsolete, since recent `pstricks.sty` versions do load `xcolor`, whereas `pstcol` is no longer needed.

³This command is executed automatically if the package option `hyperref` is used.

the `dvipsnames` option, whenever one of the `dvips`, `oztex`, `xdvi` drivers is selected. This makes documents less portable, since whenever one of these colors is used without explicit `dvipsnames` option, other drivers like `pdftex` will issue error messages because of unknown colors. Therefore, `xcolor` always requires an explicit `dvipsnames` option to use these names — which then works for all drivers.

2.1.3 Executing additional initialisation commands

`\xcolorcmd` Here is a simple interface to pass commands that should be executed at the end of the `xcolor` package (immediately before the initialising `\color{black}` is executed). Just say `\def\xcolorcmd{<commands>}` at some point before `xcolor` is loaded.

Example: assuming that `a.tex` is a complete L^AT_EX document, a command like `'latex \def\xcolorcmd{\colorlet{black}{red}}\input{a}'` at the console generates a file `a.dvi` with all occurrences of `black` being replaced by `red`, without the necessity to change the source file itself. (The exact spelling of the console command might vary across operating systems and T_EX distributions.)

2.2 Color models

2.2.1 Supported color models

The list of supported color models and their parameter ranges is given in table 3 on page 10. We emphasize that this color support is independent of the chosen driver.

'Color model support' also means that it is possible to specify colors directly with their parameters, e.g., by saying `\textcolor[cm]{0.7,0.5,0.3}{foo}` (`foo`) or `\textcolor[HTML]{AFFE90}{foo}` (`foo`).

`\adjustUCRBG` **rgb, cmyk, hsb, gray** These are the models supported by PostScript directly. We therefore refer to [1] for a description of their properties and relations. There is a special command to fine-tune the mechanisms of *undercolor-removal* and *black-generation* during conversion to the **cmyk** model, see section 6.3.2 on page 50 for details.

cm This is mainly a model for intermediary calculation steps. With respect to that, it is a simple complement of **rgb**. As far as visualisation is concerned, **cm** is treated as **cmyk** with $k = 0$.

HTML This is a model derived from **rgb** in order to enable input of color parameters from web pages or CSS files. Therefore, it is not really a color model of its own right, but rather a user interface for convenience. It is worth mentioning that **HTML** accepts any combination of the characters 0–9, A–F, a–f, as long as the string has a length of exactly 6 characters. However, outputs of conversions to **HTML** will always consist of numbers and *uppercase* letters.

`\rangeHsb` **Hsb, tHsb** Firstly, **Hsb** is a 'user interface' model, mapping $hue \in [0, 1]$ onto $hue^\circ \in [0, H]$, where H is given by `\def\rangeHsb{<H>}`. Thus, if $H = 360$, we can think of a circle or wheel to specify the hue° parameter. Secondly, **Hsb** is the basis for **tHsb**, also named *tuned Hsb*, which enables the user

Table 1: Package options

<i>Option</i>	<i>Description</i>
<code>natural</code>	(Default.) Keep all colors in their model, except RGB (converted to rgb), HSB (converted to hsb), and Gray (converted to gray).
<code>rgb</code>	Convert all colors to the rgb model.
<code>cmY</code>	Convert all colors to the cmY model.
<code>cmYk</code>	Convert all colors to the cmYk model.
<code>hsb</code>	Convert all colors to the hsb model.
<code>gray</code>	Convert all colors to the gray model. Especially useful to simulate how a black & white printer will output the document.
<code>RGB</code>	Convert all colors to the RGB model (and afterwards to rgb).
<code>HTML</code>	Convert all colors to the HTML model (and afterwards to rgb).
<code>HSB</code>	Convert all colors to the HSB model (and afterwards to hsb).
<code>Gray</code>	Convert all colors to the Gray model (and afterwards to gray).
<code>dvipsnames, dvipsnames*</code>	Load a set of predefined colors. ¹
<code>svgnames, svgnames*</code>	Load a set of predefined colors according to SVG 1.1. ¹
<code>x11names, x11names*</code>	Load a set of predefined colors according to Unix/X11. ¹
<code>table</code>	Load the <code>colortbl</code> package, in order to use the tools for coloring rows, columns, and cells within tables.
<code>fixpdftex</code>	Load the <code>pdfcolmk</code> package, in order to improve <code>pdftex</code> 's color behaviour (see section 2.15.2 on page 30).
<code>pst</code>	Load the <code>pstcol</code> package, in order to use ‘normal’ color definitions within <code>pstricks</code> macros (see footnote 2 on page 7).
<code>hyperref</code>	Support the <code>hyperref</code> package in terms of color expressions by defining additional keys (see section 2.10 on page 27).
<code>prologue</code>	Write prologue information to <code>.xcp</code> file for every color definition (as described in section 2.5.1 on page 18).
<code>kernelFbox</code>	Use L ^A T _E X kernel method to draw <code>\f(rame)box</code> frames ² .
<code>xcdraw</code>	Use driver-specific commands to draw frames and color boxes. ²
<code>noxcdraw</code>	(Default.) Use generic code to draw frames and color boxes. ²
<code>showerrors</code>	(Default.) Display an error message if an undefined color is being used (same behaviour as in the original <code>color</code> package).
<code>hideerrors</code>	Display only a warning if an undefined color is being used, and replace this color by <i>black</i> .

¹ See section 2.4.2 on page 17. ² See section 2.6.2 on page 22.

Table 2: Package loading order

<i>Action/Package</i>	color	colortbl	pdfcolmk	pstcol	hyperref
load before xcolor	no	no	no	no	allowed
load with xcolor option	—	table	fixpdxftex	pst ¹	—
load after xcolor	no	no	allowed	no	allowed

¹ not recommended, better use recent **pstricks.sty**

Table 3: Supported color models

<i>Name</i>	<i>Base colors/notions</i>	<i>Parameter range</i>	<i>Default</i>
rgb	<i>red, green, blue</i>	$[0, 1]^3$	
cmY	<i>cyan, magenta, yellow</i>	$[0, 1]^3$	
cmYk	<i>cyan, magenta, yellow, black</i>	$[0, 1]^4$	
hsb	<i>hue, saturation, brightness</i>	$[0, 1]^3$	
Hsb	<i>hue[°], saturation, brightness</i>	$[0, H] \times [0, 1]^2$	$H = 360$
tHsb	<i>hue[°], saturation, brightness</i>	$[0, H] \times [0, 1]^2$	$H = 360$
gray	<i>gray</i>	$[0, 1]$	
RGB	<i>Red, Green, Blue</i>	$\{0, 1, \dots, L\}^3$	$L = 255$
HTML	<i>RRGGBB</i>	$\{000000, \dots, \text{FFFFFF}\}$	
HSB	<i>Hue, Saturation, Brightness</i>	$\{0, 1, \dots, M\}^3$	$M = 240$
Gray	<i>Gray</i>	$\{0, 1, \dots, N\}$	$N = 15$
wave	<i>lambda (nm)</i>	$[363, 814]$	

L, M, N are positive integers; H is a positive real number

to apply a piecewise linear transformation on hue° by shifting selected hue° values forward or backward on the circle. This transformation is defined by $\backslash\text{rangetHsb}\{x_1, y_1; x_2, y_2; \dots\}$ which specifies that $hue^\circ = x_1$ in **tHsb** means $hue^\circ = y_1$ in **Hsb**, etc. For example, *yellow* is at 60° in the **Hsb** circle (*red* being at 0°), however, in most color wheels used by artists, *yellow* is at 120° . Therefore, a ‘120,60’ entry would make sense if we planned to replicate an artist’s color wheel via **tHsb**. See section 6.3.6 on page 53 for the exact transformation formula and further restrictions, and section 1.4 on page 5 for color wheels and color harmonies. Figure 11 on page 36 may serve for comparison purposes.

Example: ‘ $\backslash\text{def}\backslash\text{rangetHsb}\{60, 30; 120, 60; 180, 120; 210, 180; 240, 240\}$ ’ is in fact **xcolor**’s default setting.

wave With this model we try to make wavelengths transformable to standard color models, in order to approximate the visual appearance of light waves. While the visible spectrum covers a range of approximately 400–750 nm, the implementation in **xcolor** generally allows for all real ‘wavelengths’ λ that have an absolute value less than 16383.99998 (the biggest number **T_EX** can represent as a dimension). However, the probability of getting any non-black color outside the range of $\lambda \in [363, 814]$ is exactly zero. Therefore, figure 1 on page 31 illustrates only

the mentioned wavelength interval. Note that it is not possible to convert other models to **wave** in a sensible way, since the latter covers only a limited range of colors.

RGB, HSB, Gray These are derived models, turning the continuous $[0, 1]$ parameter ranges of **rgb**, **hsb**, and **gray** to finite sets of integers; we therefore use the term *integer models*. The constants L, M, N of table 3 are defined via the commands `\def\rangeRGB{<L>}`, `\def\rangeHSB{<M>}`, and `\def\rangeGray{<N>}`. Changes of these constants can be done *before* or *after* the xcolor package is loaded, e.g.,

```
\documentclass{article}
...
\def\rangeRGB{15}
\usepackage[dvips]{xcolor}
...
\GetGinDriver
\usepackage[\GinDriver]{hyperref}
...
\begin{document}
...
\def\rangeRGB{63}
...
```

2.2.2 Substituting individual color models

`\substitutecolormodel` `{<source model>}{<target model-list>}`

Substitute `<source model>` by the first actually present model that occurs in `<target model-list>`. Only color models of type `<num model>` are allowed; all changes are local to the current group, but a prepended `\xglobal` is obeyed.

Example: assume the actual driver has an incorrect implementation of **hsb** whereas **rgb** looks well. Then `\substitutecolormodel{hsb}{rgb}` could be a good choice, since it converts — from that point onwards — all definitions of **hsb** colors by xcolor's algorithms into **rgb** specifications, without touching other models.

2.2.3 Changing the target color model within a document

`\selectcolormodel` `{<num model>}`

Sets the target model to `<num model>`, where the latter is one of the model names allowed as package option (i.e., **natural**, **rgb**, **cm**y, **cm**yk, **hsb**, **gray**, **RGB**, **HTML**, **HSB**, **Gray**), see figure 4 on page 33 for an example. There are two possible hooks, where the conversion to the target model can take place:

- `\ifconvertcolorsD`
 - at color *definition* time⁴ (i.e., within `\definecolor` and friends); this is controlled by the switch `\ifconvertcolorsD`;
- `\ifconvertcolorsU`
 - at time of color *usage* (immediately before a color is displayed, therefore covering colors that have been defined in other models or that are being specified directly like `\color[rgb]{.1,.2,.3}`); this is controlled by the switch `\ifconvertcolorsU`.

⁴This means that all *newly* defined colors will be first converted to the target model, then saved.

Both switches are set to ‘true’ by selecting any of the models, except **natural**, which sets them to ‘false’. This applies for selection via a package option as well as via `\selectcolormodel`. Why don’t we simply convert all colors at time of usage? If many colors are involved, it can save some processing time when all conversions are already done during color definitions. Best performance can be achieved by saying `\usepackage[rgb,...]{xcolor}\convertcolorsUfalse`, which is actually the way how xcolor worked up to version 1.07.

2.3 Arguments and terminology

Before we describe xcolor’s color-related commands in detail, we define several elements or identifiers that appear repeatedly within arguments of those commands. A general syntax overview is given in table 4 on the following page.

2.3.1 Additional remarks and restrictions on arguments

$\langle \text{empty} \rangle$
 $\langle \text{minus} \rangle$
 $\langle \text{plus} \rangle$
 $\langle \text{int} \rangle$
 $\langle \text{num} \rangle$
 $\langle \text{dec} \rangle$
 $\langle \text{pct} \rangle$
 $\langle \text{div} \rangle$

Basic strings and numbers These arguments do not need much explanation. However, as far as numerical values are concerned, it is noteworthy that real numbers in (La)TeX are — as long as they are to be used in the context of lengths, dimensions, or skips — are restricted to a maximum absolute value < 16384 . Certainly, in a chain of numerical calculations, this constraint has also to be obeyed for every single interim result, which usually implies further range restrictions. Since xcolor makes extensive use of TeX’s internal dimension registers for most types of calculations, this should be kept in mind whenever $\langle \text{ext expr} \rangle$ expressions are to be used.

$\langle \text{name} \rangle$

Color names A $\langle \text{name} \rangle$ denotes the declared name (or the name to be declared) of a *color* or a *color series*; it may be declared *explicitly* by one of the following commands: `\definecolor`, `\providecolor`, `\colorlet`, `\definecolorset`, `\providecolorset`, `\definecolorseries`, `\definecolors`, `\providecolors`. On the other hand, the reserved color name ‘.’ is declared *implicitly* and denotes the *current color*. Actually, besides letters and digits, certain other characters do also work for $\langle \text{name} \rangle$ declarations, but the given restriction avoids misunderstandings and ensures compatibility with future extensions of xcolor. Examples: ‘red’, ‘MySpecialGreen1980’, ‘.’.

$\langle \text{core model} \rangle$
 $\langle \text{num model} \rangle$
 $\langle \text{model} \rangle$

Color models The differentiation between *core models* (**rgb**, **cm**y, **cm**yk, **h**sb, **gray**), *integer models* (**RGB**, **HTML**, **HSB**, **Gray**), *decimal models* (**Hsb**, **tHsb**, **wave**) and *pseudo models* (currently ‘named’, ‘ps’) has a simple reason: core models with their parameter ranges based on the unit interval $[0, 1]$ are best suited for all kinds of calculations, whereas the purpose of the integer models is mainly to facilitate the input of parameters, followed by some transformation into one of the core models. Finally, the decimal models **Hsb** and **tHsb** are special-purpose versions of **h**sb, whereas **wave** and the pseudo model ‘named’ have a special status, since they are ‘calculation-averse’: it is usually only possible to convert such a color into one of the other models, but not the other way round. Even worse for the pseudo model ‘ps’: since such colors contain PostScript code, they are absolutely intransparent for TeX.

Table 4: Arguments and terminology

<i>Element</i>	<i>Replacement string</i>	
$\langle \text{empty} \rangle$	\rightarrow empty string ‘’	
$\langle \text{minus} \rangle$	\rightarrow non-empty string consisting of one or more minus signs ‘-’	
$\langle \text{plus} \rangle$	\rightarrow non-empty string consisting of one or more plus signs ‘+’	
$\langle \text{int} \rangle$	\rightarrow integer number	(integer)
$\langle \text{num} \rangle$	\rightarrow non-negative integer number	(number)
$\langle \text{dec} \rangle$	\rightarrow real number	(decimal)
$\langle \text{div} \rangle$	\rightarrow non-zero real number	(divisor)
$\langle \text{pct} \rangle$	\rightarrow real number from the interval $[0, 100]$	(percentage)
$\langle \text{id} \rangle$	\rightarrow non-empty string consisting of letters and digits	(identifier)
$\langle \text{ext id} \rangle$	$\rightarrow \langle \text{id} \rangle$ $\rightarrow \langle \text{id} \rangle_1 = \langle \text{id} \rangle_2$	
$\langle \text{id-list} \rangle$	$\rightarrow \langle \text{ext id} \rangle_1, \langle \text{ext id} \rangle_2, \dots, \langle \text{ext id} \rangle_l$	
$\langle \text{name} \rangle$	$\rightarrow \langle \text{id} \rangle$ $\rightarrow \text{‘.’}$	(explicit name) (implicit name)
$\langle \text{core model} \rangle$	$\rightarrow \text{‘rgb’}, \text{‘cmy’}, \text{‘cmyk’}, \text{‘hsb’}, \text{‘gray’}$	(core models)
$\langle \text{num model} \rangle$	$\rightarrow \langle \text{core model} \rangle$ $\rightarrow \text{‘RGB’}, \text{‘HTML’}, \text{‘HSB’}, \text{‘Gray’}$ $\rightarrow \text{‘Hsb’}, \text{‘tHsb’}, \text{‘wave’}$	(integer models) (decimal models)
$\langle \text{model} \rangle$	$\rightarrow \langle \text{num model} \rangle$ $\rightarrow \text{‘named’}$	(numerical models) (pseudo model)
$\langle \text{model-list} \rangle$	$\rightarrow \langle \text{model} \rangle_1 / \langle \text{model} \rangle_2 / \dots / \langle \text{model} \rangle_m$ $\rightarrow \langle \text{core model} \rangle : \langle \text{model} \rangle_1 / \langle \text{model} \rangle_2 / \dots / \langle \text{model} \rangle_m$	(multiple models)
$\langle \text{spec} \rangle$	\rightarrow comma-separated list of numerical values \rightarrow name of a ‘named’ color	(explicit specification) (implicit specification)
$\langle \text{spec-list} \rangle$	$\rightarrow \langle \text{spec} \rangle_1 / \langle \text{spec} \rangle_2 / \dots / \langle \text{spec} \rangle_m$	(multiple specifications)
$\langle \text{type} \rangle$	$\rightarrow \langle \text{empty} \rangle$ $\rightarrow \text{‘named’}, \text{‘ps’}$	
$\langle \text{expr} \rangle$	$\rightarrow \langle \text{prefix} \rangle \langle \text{name} \rangle \langle \text{mix expr} \rangle \langle \text{postfix} \rangle$	(standard color expression)
$\langle \text{prefix} \rangle$	$\rightarrow \langle \text{empty} \rangle$ $\rightarrow \langle \text{minus} \rangle$	(complement indicator)
$\langle \text{mix expr} \rangle$	$\rightarrow ! \langle \text{pct} \rangle_1 ! \langle \text{name} \rangle_1 ! \langle \text{pct} \rangle_2 ! \langle \text{name} \rangle_2 ! \dots ! \langle \text{pct} \rangle_n ! \langle \text{name} \rangle_n$ $\rightarrow ! \langle \text{pct} \rangle_1 ! \langle \text{name} \rangle_1 ! \langle \text{pct} \rangle_2 ! \langle \text{name} \rangle_2 ! \dots ! \langle \text{pct} \rangle_n$	(complete mix expr.) (incomplete mix expr.)
$\langle \text{postfix} \rangle$	$\rightarrow \langle \text{empty} \rangle$ $\rightarrow !! \langle \text{plus} \rangle$ $\rightarrow !! [\langle \text{num} \rangle]$	(series step) (series access)
$\langle \text{ext expr} \rangle$	$\rightarrow \langle \text{core model} \rangle, \langle \text{div} \rangle : \langle \text{expr} \rangle_1, \langle \text{dec} \rangle_1 ; \langle \text{expr} \rangle_2, \langle \text{dec} \rangle_2 ; \dots ; \langle \text{expr} \rangle_k, \langle \text{dec} \rangle_k$ $\rightarrow \langle \text{core model} \rangle : \langle \text{expr} \rangle_1, \langle \text{dec} \rangle_1 ; \langle \text{expr} \rangle_2, \langle \text{dec} \rangle_2 ; \dots ; \langle \text{expr} \rangle_k, \langle \text{dec} \rangle_k$	
$\langle \text{func expr} \rangle$	$\rightarrow > \langle \text{function} \rangle, \langle \text{arg} \rangle_1, \langle \text{arg} \rangle_2, \dots, \langle \text{arg} \rangle_j$	(color function expression)
$\langle \text{function} \rangle$	$\rightarrow \text{‘wheel’}, \text{‘twheel’}$	(color functions)
$\langle \text{color} \rangle$	$\rightarrow \langle \text{color expr} \rangle \langle \text{func expr} \rangle_1 \langle \text{func expr} \rangle_2 \dots \langle \text{func expr} \rangle_i$	
$\langle \text{color expr} \rangle$	$\rightarrow \langle \text{name} \rangle$ $\rightarrow \langle \text{expr} \rangle$ $\rightarrow \langle \text{ext expr} \rangle$	

Remarks: Each \rightarrow denotes a possible replacement string for the element in the left column; however, further context-dependent restrictions may apply. See main text for details. A string ‘foo’ is always to be understood without the quotes. i, j, k, l, m, n denote non-negative integers, $k, l, m, n > 0$, $m \leq 8$.

$\langle spec \rangle$ **Color specifications** The $\langle spec \rangle$ argument — which specifies the parameters of a color — obviously depends on the underlying color model. We differentiate between *explicit* and *implicit* specification, the former referring to numerical parameters as explained in table 3 on page 10, the latter — ideally — referring to driver-provided names.
Examples: `‘.1,.2,.3’`, `‘0.56789’`, `‘89ABCD’`, `‘ForestGreen’`.

$\langle model-list \rangle$
 $\langle spec-list \rangle$ **Multiple models and specifications** These arguments always appear in (explicit or implicit) pairs within the following color definition commands: `\definecolor`, `\providecolor`, `\definecolorset`, `\providecolorset`. First, $\langle model-spec \rangle$ is being reconciled with the current target model (as set by a package option or the `\selectcolormodel` command); in case there is no exact match, the first model of the list is chosen. Then, the corresponding color specification will be selected from $\langle spec-list \rangle$, such that we arrive at a proper $(\langle model \rangle, \langle spec \rangle)$ pair. Therefore, in the actual executed color definition there is no ambiguity anymore. The extended form $\langle core\ model \rangle : \langle model \rangle_1 / \langle model \rangle_2 / \dots / \langle model \rangle_m$ causes an immediate conversion of the relevant $\langle spec \rangle$ to $\langle core\ model \rangle$; an unknown target model will be silently ignored here.
Examples: `‘rgb/cmyk/named/gray’`, `‘0,0,0/0,0,0,1/Black/0’`, `‘rgb:cmy/hsb’`.

$\langle type \rangle$ **The type argument** This is used only in the context of color defining commands, see the description of `\definecolor` and friends.

$\langle expr \rangle$
 $\langle prefix \rangle$
 $\langle mix\ expr \rangle$
 $\langle postfix \rangle$ **Standard color expressions** These expressions serve as a tool to easily specify a certain form of cascaded color mixing which is described in detail in section 2.3.2. The $\langle prefix \rangle$ argument controls whether the color following thereafter or its complement will be relevant: an odd number of minus signs indicates that the color resulting from the remaining expression has to be converted into its complementary color. An *incomplete mix expression* is just an abbreviation for a *complete mix expression* with $\langle name \rangle_n = \text{white}$, in order to save some keystrokes in the case of tints. The $\langle postfix \rangle$ string is usually empty, but it offers some additional functionality in the case of a *color series*: the non-empty cases require that

- $\langle name \rangle$ denotes the name of a *color series*,
- $\langle mix\ expr \rangle$ is a *complete* mix expression.

Examples: `‘red’`, `‘-red’`, `‘--red!50!green!12.345’`, `‘red!50!green!20!blue’`, `‘foo!!+’`, `‘foo!![7]’`, `‘foo!25!red!!+++’`, `‘foo!25!red!70!green!![7]’`.

$\langle ext\ expr \rangle$ **Extended color expressions** These expressions provide another method of color mixing, see section 2.3.3 on page 16 for details. The shorter form

$$\langle core\ model \rangle : \langle expr \rangle_1, \langle dec \rangle_1; \langle expr \rangle_2, \langle dec \rangle_2; \dots; \langle expr \rangle_k, \langle dec \rangle_k$$

is an abbreviation for the special (and probably most used) case

$$\langle core\ model \rangle, \langle div \rangle : \langle expr \rangle_1, \langle dec \rangle_1; \langle expr \rangle_2, \langle dec \rangle_2; \dots; \langle expr \rangle_k, \langle dec \rangle_k$$

with the following definition (requiring a non-zero sum of all $\langle dec \rangle_\kappa$ coefficients):

$$\langle div \rangle := \langle dec \rangle_1 + \langle dec \rangle_2 + \cdots + \langle dec \rangle_k \neq 0.$$

Examples: ‘`rgb:red,1`’, ‘`cmk:red,1;-green!25!blue!60,11.25;blue,-2`’.

$\langle func\ expression \rangle$
 $\langle function \rangle$

Function expressions These expressions extend the functionality of *standard* or *extended* expressions by taking the result of such an expression to perform additional calculations. The number of arguments may vary between different functions, see section 2.3.4 on the next page for details.

Examples: ‘`>wheel,30`’, ‘`>wheel,30,`’, ‘`>twheel,1,12`’, ‘`>twheel,-11,12`’.

$\langle color \rangle$
 $\langle color\ expr \rangle$

Colors Finally, $\langle color \rangle$ is the ‘umbrella’ argument, covering the different concepts of specifying colors. This means, whenever there is a $\langle color \rangle$ argument, the full range of names and expressions, as explained above, may be used.

2.3.2 Meaning of standard color expressions

We explain now how an expression

$$\langle prefix \rangle \langle name \rangle ! \langle pct \rangle_1 ! \langle name \rangle_1 ! \langle pct \rangle_2 ! \dots ! \langle pct \rangle_n ! \langle name \rangle_n \langle postfix \rangle$$

is being interpreted and processed:

1. First of all, the model and color parameters of $\langle name \rangle$ are extracted to define a temporary color $\langle temp \rangle$. If $\langle postfix \rangle$ has the form ‘`!![<num>]`’, then $\langle temp \rangle$ will be the corresponding (direct-accessed) color $\langle num \rangle$ from the series $\langle name \rangle$.
2. Then a color mix, consisting of $\langle pct \rangle_1\%$ of color $\langle temp \rangle$ and $(100 - \langle pct \rangle_1)\%$ of color $\langle name \rangle_1$ is computed; this is the new temporary color $\langle temp \rangle$.
3. The previous step is being repeated for all remaining parameter pairs $(\langle pct \rangle_2, \langle name \rangle_2), \dots, (\langle pct \rangle_n, \langle name \rangle_n)$.
4. If $\langle prefix \rangle$ consists of an odd number of minus signs ‘-’, then $\langle temp \rangle$ will be changed into its complementary color.
5. If $\langle postfix \rangle$ has the form ‘`!!+`’, ‘`!!++`’, ‘`!!+++`’, etc., a number of step commands (= number of ‘+’ signs) are performed on the underlying color series $\langle name \rangle$. This has no consequences for the color $\langle temp \rangle$.
6. Now the color $\langle temp \rangle$ is being displayed or serves as an input for other operations, depending on the invoking command.

Note that in a typical step 2 expression $\langle temp \rangle ! \langle pct \rangle_\nu ! \langle name \rangle_\nu$, if $\langle pct \rangle_\nu = 100$ resp. $\langle pct \rangle_\nu = 0$, the color $\langle temp \rangle$ resp. $\langle name \rangle_\nu$ is used without further transformations. In the true mix case, $0 < \langle pct \rangle_\nu < 100$, the two involved colors may have been defined in different color models, e.g., `\definecolor{foo}{rgb}{...}` and `\definecolor{bar}{cmk}{...}`. In general, the second color, $\langle name \rangle_\nu$, is transformed into the model of the first color, $\langle temp \rangle$, then the mix is calculated within

that model.⁵ Thus, $\langle temp \rangle! \langle pct \rangle_\nu! \langle name \rangle_\nu$ and $\langle name \rangle_\nu! \langle 100-pct \rangle_\nu! \langle temp \rangle$, which should be equivalent theoretically, will not necessarily yield identical visual results.

Figures 5 to 6 on page 33 show some first applications of colors and expressions. More examples are given in figure 3 on page 32. Over and above that, a large set of color examples can be found in [9].

2.3.3 Meaning of extended color expressions






An *extended color expression*

$$\langle core\ model \rangle : \langle expr \rangle_1, \langle dec \rangle_1; \langle expr \rangle_2, \langle dec \rangle_2; \dots; \langle expr \rangle_k, \langle dec \rangle_k$$


mimes color mixing as painters do it: specify a list of colors, each with a $\langle dec \rangle$ factor attached to. For such an $\langle ext\ expr \rangle$, each standard color expression $\langle expr \rangle_\kappa$ will be converted to $\langle core\ model \rangle$, then the resulting vector is multiplied by $\langle dec \rangle_\kappa / \langle div \rangle$, where

$$\langle div \rangle := \langle dec \rangle_1 + \langle dec \rangle_2 + \dots + \langle dec \rangle_k.$$

Afterwards the sum of all of these vectors is calculated.

Example: mixing 4 parts of  red, 2 parts of  green, and 1 part of  yellow, we get  by saying `\color{rgb:red,4;green,2;yellow,1}`. Trying the same with -1 parts of yellow instead, we get . Note that this mechanism can also be used to display an individual color (expression) in a certain color model: `\color{rgb:yellow,1}` results in such a conversion. The general form

$$\langle core\ model \rangle, \langle div \rangle : \langle expr \rangle_1, \langle dec \rangle_1; \langle expr \rangle_2, \langle dec \rangle_2; \dots; \langle expr \rangle_k, \langle dec \rangle_k$$

does the same operation with the only difference that the divisor $\langle div \rangle$ is being specified instead of calculated. In the above example, we get a shaded version  by saying `\color{rgb,9:red,4;green,2;yellow,1}`. Note that it is not forbidden to specify a $\langle div \rangle$ argument which is smaller than the sum of all $\langle dec \rangle_\kappa$, such that one or more of the final color specification parameters could be outside the interval $[0, 1]$. However, the mapping of equation (7) takes care of such cases.

2.3.4 Color functions

Color functions take a comma-separated list of arguments, and they serve to transform the *given color* (i.e., the result of all calculations prior to the function call) into a new color.

wheel **Color wheel calculations** Arguments: $\langle angle \rangle$ or $\langle angle \rangle, \langle full\ circle \rangle$, the former being an abbreviaaion of $\langle angle \rangle, \langle rangeHsb \rangle$. These functions allow to calculate related colors by harmonic relations based on color wheels (cf. section 1.4 on page 5). The second argument $\langle full\ circle \rangle$ declares how many units a full circle consists of, the first argument states by how many units the given color has to be

⁵Exception: in order to avoid strange results, this rule is being reversed if $\langle temp \rangle$ origins from the **gray** model; in this case it is converted into the underlying model of $\langle name \rangle_\nu$.


















rotated. To this end, the given color is first converted to **Hsb** (in case of *wheel*), yielding hue° , *saturation*, and *brightness*, respectively. Then

$$hue^\circ := hue^\circ + \frac{\langle angle \rangle}{\langle full\ circle \rangle} \cdot H, \quad hue := u\left(\frac{hue^\circ}{H}\right) \quad (4)$$

where u is the range-reduction function of equation (7) and $H = \backslash rangeHsb$. With *saturation* and *brightness* left untouched, the final model is **hsb**. The *twheel* function works similarly, but its arguments refer to **tHsb** instead of **Hsb**. Examples are shown in figure 12 on page 37.

2.4 Predefined colors

2.4.1 Colors that are always available

Within `xcolor.sty`, the following color names are defined:  *red*,  *green*,  *blue*,  *cyan*,  *magenta*,  *yellow*,  *orange*,  *violet*,  *purple*,  *brown*,  *pink*,  *olive*,  *black*,  *darkgray*,  *gray*,  *lightgray*,  *white*.

This base set of colors can be used without restrictions in all kinds of color expressions, as explained in section 2.3 on page 12.

2.4.2 Additional sets of colors

There are also sets of color names that may be loaded by `xcolor` via package options, available in two variants: a ‘normal’ version (e.g., `dvipsnames`) and a ‘starred’ version (e.g., `dvipsnames*`). The first variant simply defines all the colors *immediately*, whereas the second applies the mechanism of *deferred* definition. In the latter case, individual color names have to be activated by `\definecolors` or `\providecolors` commands, as described in section 2.5.4 on page 20, before they can be applied in a document.

- `dvipsnames/dvipsnames*` loads a set of 68 **cmymk** colors as defined in the `dvips` driver. However, these colors may be used in all supported drivers.
- `svgnames/svgnames*` loads a set of 151 **rgb** color names⁶ according to the SVG 1.1 specification [16]⁷, enhanced by 4 names taken from the file `rgb.txt` which is part of Unix/X11 distributions.
- `x11names/x11names*` loads a set of 317 **rgb** color names⁸ that are basically variations of a subset of the SVG set mentioned before, according to the file `rgb.txt` which is part of Unix/X11 distributions⁹. We describe now how to access all 752 color names of `rgb.txt` without much effort:

- Load `x11namees` as well as `svgnames`.
- Capitalise initials and skip blanks: *DarkSlateGray* instead of *dark slate gray*.

⁶In fact, these names represent 141 different colors.

⁷Actually, the cited specification lists only lowercase names, and the original definitions are given in **RGB** parameters, converted to **rgb** by the author.

⁸These names represent 315 different colors.

⁹Again, the original definitions are given in **RGB** parameters, converted to **rgb** by the author.

- X11 names without numbers are identical to the corresponding SVG colors, except in 5 cases: use *Gray0*, *Grey0*, *Green0*, *Maroon0*, *Purple0* instead of *Gray*, *Grey*, *Green*, *Maroon*, *Purple* to obtain the original X11 colors.
- For $N = 0, 1, \dots, 100$ use ‘`[gray]{N/100}`’ or ‘`black!100 – N`’ instead of *grayN* or *greyN*.

The color names and corresponding displays are listed in section 4 on page 38. Section 2.15.1 on page 29 describes how to deal with name clashes while using both `svgnames` and `dvipsnames` in the same document. See also [9] for a systematic set of color and mix examples.

2.5 Color definition

2.5.1 Ordinary and named colors

In the `color` package there is a distinction between ‘colors’ (defined by the command `\definecolor`) and ‘named colors’ (defined by `\DefineNamedColor`, which is allowed only in the preamble). Whenever an ordinary color is being used in a document, it will be translated into a `\special` command that contains a — driver-specific — numerical description of the color which is written to the `.dvi` file. On the other hand, named colors offer the opportunity to store numerical values at a central place whereas during usage, colors may be identified by their names, thus enabling post-processing if required by the output device.

All drivers delivered with the standard `graphics` package support the *formalism* of defining and invoking ‘named colors’. However, real support for the *concept* behind that, i.e. employing names instead of parameters, ranges from ‘none’ to ‘complete’. We demonstrate the current situation for three different drivers:

- `dvips` has very good support for the ‘named’ concept; the PostScript equivalents to the color names defined by `dvipsnames` are being loaded – unless switched off – by `dvips` automatically. However, additional names have to be made known to the PostScript interpreter by some kind of header file. Since version 2.01, `xcolor` offers an integrated solution for this task: by invoking the package option `prologue`, a PostScript header file `xcolor.pro` is loaded by `dvips`. Additionally, under this option every color definition command¹⁰ (`\definecolor`, `\colorlet`, etc.) will generate some PostScript code that is written to an auxiliary file with the extension `.xcp` (shortcut for `xcolor prologue`). This file is as well loaded by `dvips` as a prologue, thus making all color names available to the PostScript interpreter. Of course, the `.xcp` file may be edited before `dvips` is applied, making it easy to change device-specific color parameters at a central place. Note that the PostScript code is designed similar to `color.pro`: only *new* names are defined. This allows to preload other prologue files with color definitions that are not being destroyed by `xcolor`. On the other hand, it requires the user to take care about redefining color names.

Example: `\colorlet{foo}{red}\colorlet{foo}{blue}\color{foo}` will switch to *blue* in the usual `xcolor` logic, however the `.ps` file would display *red* (unless *foo* had been defined differently before).

¹⁰This is not only true for the document preamble, but for the document body as well.

It should be stressed that this mechanism is only employed by the `prologue` option. Without that, the predefined ‘named’ colors activated by the `dvipsnames` option (without employing any tints, shades, color expressions, etc.) may be used in this way, all other ‘named’ colors are unknown to PostScript.

- `dvipdfm` supports only the standard `dvipsnames` colors since these are hard-coded in the `dvipdfm` program itself; there seems to be no way to load any user-defined prologue files.
- `pdftex` does not offer conceptual support, all ‘named’ colors are converted immediately to their numerical representation. It therefore allows unrestricted definition and usage of named colors (although offering no added value through this).

Typically, a `.dvi` viewer will have difficulties to display user-defined ‘named’ colors. For example, MiKTeX’s viewer *Yap* currently displays only ‘named’ colors from the `dvipsnames` set. Thus, whenever the `prologue` option is invoked together with `dvips`, *all* other colors will appear black. However, after employing `dvips`, a PostScript viewer should display the correct colors.

2.5.2 Color definition in xcolor

`\definecolor` [*type*] {*name*} {*model-list*} {*spec-list*}¹¹

This is one of the commands that may be used to assign a *name* to a specific color. Afterwards, this color is known to the system (in the current group) and may be used in *color expressions*, as explained in section 2.3 on page 12. It replaces both color’s `\DefineNamedColor` and `\definecolor`. Note that an already existing color *name* will be overwritten. The variable `\tracingcolors` controls whether such an overwriting will be logged or not (see section 2.13 on page 28 for details). The arguments are described in section 2.3 on page 12. Hence, valid expressions for color definitions are

- `\definecolor{red}{rgb}{1,0,0},`
- `\definecolor{red}{rgb/cmyk}{1,0,0/0,1,1,0},`
- `\definecolor{red}{hsb:rgb/cmyk}{1,0,0/0,1,1,0},`
- `\definecolor[named]{Black}{cmyk}{0,0,0,1},`
- `\definecolor{myblack}{named}{Black},`

where the last command is equivalent to `\colorlet{myblack}{Black}` (see below); the second command defines *red* in the **rgb** or **cmyk** model, depending on the current setting of the *target model*, whereas the third will additionally transform the color to **hsb** prior to saving. Note that there is a special `pstricks` version as described in section 2.11 on page 28.

`\providecolor` [*type*] {*name*} {*model-list*} {*spec-list*}

Similar to `\definecolor`, but the color *name* is only defined if it does not exist already.

`\colorlet` [*<type>*]{*<name>*}[*<num model>*]{*<color>*}

Copies the actual color which results from *<color>* to *<name>*. If *<num model>* is non-empty, *<color>* is first transformed to the specified model, before *<name>* is being defined. The pseudo model ‘named’ is *not* allowed here, it may, however, be specified in the *<type>* argument. Note that an already existing color *<name>* will be overwritten.

Example: we said `\colorlet{tableheadcolor}{gray!25}` in the preamble of this document. In most of the tables we then formatted the first row by using the command `\rowcolor{tableheadcolor}`.

2.5.3 Defining sets of colors

`\definecolorset` [*<type>*]{*<model-list>*}[*<head>*]{*<tail>*}[*<set spec>*]

This command facilitates the construction of *color sets*, i.e. (possibly large) sets of individual colors with common underlying *<model-list>* and *<type>*. Here, *<set spec>* = *<name>*₁,*<spec-list>*₁;...;*<name>*_l,*<spec-list>*_l (*l* ≥ 1 name/specification-list pairs). Individual colors are being constructed by single

`\definecolor` [*<type>*]{*<head>**<name>*_λ*<tail>*}[*<model-list>*]{*<spec-list>*_λ}

commands, *λ* = 1, ..., *l*. For example,

- `\definecolorset{rgb}{}{}{red,1,0,0;green,0,1,0;blue,0,0,1}`
could be used to define the basic colors *red*, *green*, and *blue*;¹²
- `\definecolorset{rgb}{x}{10}{red,1,0,0;green,0,1,0;blue,0,0,1}`
would define the colors *xred10*, *xgreen10*, and *xblue10*.

`\providecolorset` [*<type>*]{*<model-list>*}[*<head>*]{*<tail>*}[*<set spec>*]

Similar to `\definecolorset`, but based on `\providecolor`, thus the individual colors are defined only if they do not exist already.

2.5.4 Immediate and deferred definitions

Traditionally, the definition of a color as described above leads to the immediate construction of a command that holds at least the information needed by the driver to display the desired color. Thus, defining 300 colors, e.g., by loading a huge set of predefined colors, will result in 300 new commands, although most of them — except for the purpose of displaying lists of colors — will hardly ever be used within a document. Along the development of computer memory — increasing in size, decreasing in price — recent T_EX implementations have increased their provisions for internal memory stacks that are available for strings, control sequences, etc. However, as memory continues to be finite, it may still be useful (or occasionally necessary) to have a method at hand that allows to reduce memory requirements a bit. This is the point where *deferred color definition* comes into play. Its principle is simple: for every definition of this type (e.g., via `\preparecolor`), all necessary information is saved on a specific global *definition stack*, where it can be taken from later (e.g., via `\definecolors`) in order to construct the actual color command.

¹¹Prior to version 2.00, this command was called `\xdefinecolor`, the latter name still being available for compatibility reasons.

¹²Actually, xcolor uses a more complicated variant to provide the basic colors for different underlying models (see the source code for the full command):
`\definecolorset{rgb/hsb/cmyk/gray}{}{}{red,1,0,0/0,1,1/0,1,1,0/.3;green,...}`.

Note that the following commands are only to be used in the document preamble, since the definition stack of colors for deferred definitions is deleted at the begin of the document body — in order to save memory.

`\preparecolor` [*<type>*]{*<name>*}{*<model-list>*}{*<spec-list>*}

Similar to `\definecolor`, but the color *<name>* is not yet being defined: the arguments *<model-list>* and *<spec-list>* are evaluated immediately, then all necessary parameters (i.e. *<type>*, *<name>*, *<model>*, *<spec>*) are put onto the *definition stack* for later usage.

`\preparecolorset` [*<type>*]{*<model-list>*}{*<head>*}{*<tail>*}{*<set spec>*}

`\ifdefinecolors` Similar to `\definecolorset`, but depending on the `\ifdefinecolors` switch: if set to ‘true’, to each element of the set the command `\definecolor` (i.e. immediate definition) is applied; if set to ‘false’, `\preparecolor` (i.e. deferred definition) is applied. For example, the package option `svgnames` performs something like `\definecolorstrue\preparecolorset`, whereas `svgnames*` acts like `\definecolorsfalse\preparecolorset`. Both options set `\definecolorstrue` at the end, in order to have a proper starting point for other color sets.

`\DefineNamedColor` {*<type>*}{*<name>*}{*<model-list>*}{*<spec-list>*} is provided mainly for compatibility reasons, especially to support the predefined colors in `dvipsnam.def`. It is the same as `<cmd>[<type>]{<name>}{<model>}{<spec>}`, where `<cmd>` is either `\definecolor` or `\preparecolor`, depending on the state of `\ifdefinecolors`. Note that `color`’s restriction to allow `\DefineNamedColor` only in the document preamble has been abolished in `xcolor`.

`\definecolors` {*<id-list>*}

Recall that *<id-list>* has the form $\langle ext\ id \rangle_1, \dots, \langle ext\ id \rangle_l$ where each $\langle ext\ id \rangle_\lambda$ is either an identifier $\langle id \rangle_\lambda$ or an assignment $\langle id \rangle_\lambda = \langle id \rangle_\lambda$. We consider the first case to be an abbreviation for $\langle id \rangle_\lambda = \langle id \rangle_\lambda$ and describe the general case: the definition stack is searched for the name $\langle id \rangle_\lambda$ and its corresponding color parameters; if there is no match, nothing happens; if the name $\langle id \rangle_\lambda$ is on the stack and its color parameters are $\langle type \rangle_\lambda$, $\langle model \rangle_\lambda$, and $\langle spec \rangle_\lambda$, then the command `\definecolor[<type>]{<id>}{<model>}{<spec>}` is executed. Thus, the user may control by which names the *prepared* colors are to be used in the document. Note that the entry $\langle id \rangle_\lambda$ is not removed from the stack, such that it can be used several times (even within the same `\definecolors` command).

`\providecolors` {*<id-list>*}

Similar to `\definecolors`, but based on `\providecolor`, thus the individual colors are defined only if they do not exist already.

2.5.5 Global color definitions

`\ifglobalcolors` By default, definitions via `\definecolor`, `\providecolor`, ... are available only within the current group. By setting `\globalcolorstrue`, all such definitions are being made globally available — until the current group ends.¹³ Another method to specify that an individual color definition is to be made global is to prefix it by `\xglobal`, e.g., `\xglobal\definecolor{foo}...`

¹³The switch may also be set in the preamble in order to control the whole document.

2.6 Color application

2.6.1 Standard color commands

Here is the list of user-level color commands, as known from the `color` package, but with an extended syntax for the colors, allowing for expressions etc.:

<code>\color</code>	<code>{\color}</code> <code>[\model-list]{\spec-list}</code> Switches to the color given either by name/expression or by model/specification. This color will stay in effect until the end of the current \TeX group.
<code>\textcolor</code>	<code>{\color}{\text}</code> <code>[\model-list]{\spec-list}{\text}</code> are just alternative syntax for <code>\color</code> , in which the groups are added implicitly. Thus <code>\text</code> appears in the specified color, but then the color reverts to its previous value. Additionally, it calls <code>\leavevmode</code> to ensure the start of horizontal mode.
<code>\pagecolor</code>	<code>{\color}</code> <code>[\model-list]{\spec-list}</code> Specifies the background color for the current, and all following, pages. It is a global declaration which does not respect \TeX groups. Remark: all of these commands except <code>\color</code> require that the <code>\color</code> resp. <code>\spec</code> arguments are put into curly braces {}, even if they are buried in macros. For example, after <code>\def\foo{red}</code> , one may say <code>\color\foo</code> , but one should always write <code>\textcolor{\foo}{bar}</code> instead of <code>\textcolor\foo{bar}</code> in order to avoid strange results. Note that color-specific commands from other packages may give unexpected results if directly confronted with color expressions (e.g., <code>soul</code> 's <code>\sethlcolor</code> and friends). However, one can turn the expression into a name via <code>\colorlet</code> and try to use that name instead.

2.6.2 Colored boxes

<code>\colorbox</code>	<code>{\color}{\text}</code> <code>[\model-list]{\spec-list}{\text}</code> Takes the same argument forms as <code>\textcolor</code> , but the color specifies the <i>background</i> color of the box.
<code>\fcolorbox</code>	<code>{\frame color}{\background color}{\text}</code> <code>[\model-list]{\frame spec-list}{\background spec-list}{\text}</code> <code>[\fr. model-list]{\fr. spec-list}[\backgr. model-list]{\backgr. spec-list}{\text}</code> <code>{\frame color}[\background model-list]{\background spec-list}{\text}</code> Puts a frame of the first color around a box with a background specified by the second color. If only the first optional argument is given, it specifies the color model for both colors. Besides the possibility to specify color <i>expressions</i> as arguments, <code>\fcolorbox</code> now offers more flexibility for its arguments than the <code>color</code> version:

- `\fcolorbox{gray}{yellow}{test},`
- `\fcolorbox[cm]{0,0,0,0.5}{0,0,1,0}{test},`
- `\fcolorbox[gray]{0.5}[wave]{580}{test},`
- `\fcolorbox{gray}[wave]{580}{test}.`

Additionally, `\fcolorbox` uses a new approach to frame drawing, which is an extension of Donald Arseneau's suggestion in bug report latex/3655 [2]. The main difference to L^AT_EX's implementation is that box construction and frame drawing are split into separate operations, such that the frame is drawn *after* the box contents has been constructed. This ensures that the frame is always on top of the box. Donald Arseneau improved speed as well as memory requirements of this approach. Furthermore, a new macro is introduced:

`\boxframe` $\{\langle width \rangle\}\{\langle height \rangle\}\{\langle depth \rangle\}$

Draws a frame with a linewidth of `\fboxrule`. Returns a `\hbox` with outer dimensions $\langle width \rangle$, $\langle height \rangle$, $\langle depth \rangle$. By this approach, a frame-primitive may also be provided by a driver file, in order to exploit driver-specific drawing facilities (see below). Again, this macro was optimised by Donald Arseneau.

The new frame approach is used for `\fcolorbox` as well as L^AT_EX's `\fbox` and `\framebox` commands, unless the `\kernel fbox` option is specified, which returns to L^AT_EX's original definitions of `\f(rame)box`.

Option `xcdraw` uses PostScript commands to draw frames and color boxes in case of the `dvips` driver. This is still experimental code that may confuse `.dvi` viewers. The opposite option `noxcdraw` forces usage of the generic (driver-independent) code.

2.6.3 Using the current color

Within a color expression, `'.'` serves as a placeholder for the current color. See figure 7 on page 33 for an example.

It is also possible to save the current color for later use, e.g., via the command `\colorlet{foo}{.}`.

Note that in some cases the current color is of rather limited use, e.g., the construction of an `\fcolorbox` implies that at the time when the $\langle background\ color \rangle$ is evaluated, the current color equals the $\langle frame\ color \rangle$; in this case `'.'` does not refer to the current color *outside* the box.

2.6.4 Color testing

`testcolors` $[\langle num\ models \rangle]$

This is a simple tabular environment in order to test (display) colors in different models, showing both the visual result and the model-specific parameters. The optional $\langle num\ models \rangle$ argument is a comma-separated list of *numerical* color models (as usual without spaces) which form the table columns; the default list is `rgb,cmym,hsb,HTML`.

`\testcolor` $\{\langle color \rangle\}$
 $[\langle model-list \rangle]\{\langle spec-list \rangle\}$

Each `\testcolor` command generates a table row, containing a display sample plus the respective parameters for each of the models. If the column-model matches the model of the color in question, its parameters are underlined. Note that this command is only available within the `testcolors` environment.




For applications see figure 2 on page 31 and figures 11, 12.

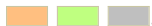

2.7 Color blending

The purpose of *color blending* is to add some mixing color (expression) to all subsequent explicit color commands. Thus, it is possible to perform such a mix (or blend) operation for many colors without touching the individual commands.

`\blendcolors` $\{\langle mix\ expr \rangle\}$
`\blendcolors*` $\{\langle mix\ expr \rangle\}$

Initialises all necessary parameters for color blending. The actual (completed) color blend expression is stored in `\colorblend`. In the starred version, the argument will be appended to a previously defined blend expression. An empty $\langle mix\ expr \rangle$ argument will switch blending off.

Example: after `\blendcolors{!50!yellow}`, the colors  are transformed into , an additional `\blendcolors*{!50}` yields .

`\xglobal` In order to achieve global scope, `\blendcolors` may be prefixed by `\xglobal`.
 Remark: color blending is applied only to *explicit* color commands, i.e. `\color`, `\fcolorbox` and the like. In the previous example the frames are not being blended because their color is set by an driver-internal command (switching back to the ‘current color’). Thus, to influence these *implicit* colors as well, we have to set the current color *after* the blending: `\blendcolors{!50!yellow}\color{black}` results in . an additional `\blendcolors*{!50}\color{black}` yields .

2.8 Color masks and separation

The purpose of *color separation* is to represent all colors that appear in the document as a combination of a finite subset of base colors and their tints. Most prominent is **cm**yk separation, where the base colors are *cyan*, *magenta*, *yellow*, and *black*, as required by the printers. This can be done by choosing the package option **cm**yk, such that all colors will be converted in this model, and post-processing the output file. We describe now another — and more general — solution: *color masking*. How does it work? Color masking is based on a specified color model $\langle m\text{-}model \rangle$ and a parameter vector $\langle m\text{-}spec \rangle$. Whenever a color is to be displayed in the document, it will first be converted to $\langle m\text{-}model \rangle$, afterwards each component of the resulting color vector will be multiplied by the corresponding component of $\langle m\text{-}spec \rangle$. For example, let’s assume that $\langle m\text{-}model \rangle$ equals **cm**yk, and $\langle m\text{-}spec \rangle$ equals $(\mu_c, \mu_m, \mu_y, \mu_k)$. Then an arbitrary color *foo* will be transformed according to

$$foo \mapsto (c, m, y, k) \mapsto (\mu_c \cdot c, \mu_m \cdot m, \mu_y \cdot y, \mu_k \cdot k) \quad (5)$$

Obviously, color separation is a special case of masking by the vectors $(1, 0, 0, 0)$, $(0, 1, 0, 0)$, etc. An interesting application is to shade or tint all colors by masking them with (x, x, x) in the **rgb** or **cm**y model, see the last two rows in figure 9 on page 35.

`\maskcolors` $[\langle num\ model \rangle]\{\langle color \rangle\}$

Initialises all necessary parameters for color masking: if $\langle num\ model \rangle$ is not specified (or empty), $\langle m\text{-}model \rangle$ will be set to the natural model of $\langle color \rangle$, otherwise to $\langle num\ model \rangle$; the color specification of $\langle color \rangle$ is extracted to define $\langle m\text{-}spec \rangle$. Additionally, `\maskcolorstrue` is performed. Color masking can be

`\ifmaskcolors` switched off temporarily by `\maskcolorsfalse`, or — in a more radical way —

- `\xglobal` by `\maskcolors{}`, which in addition clears the initialisation parameters. In general, the scope of `\maskcolors` is the current group (unless it is prefixed by the `\xglobal` command), but it may be used in the document preamble as well. The final remark of the color blending section applies here similarly. Now it is easy to separate a complete document without touching the source code: `latex \def\xcolorcmd{\maskcolors[cmyk]{cyan}}\input{a}` will do the cyan part of the job for `a.tex`.
- `\colormask` Caution: xcolor has no idea about colors in files that are included via the command `\includegraphics`, e.g., images of type `.eps`, `.pdf`, `.jpg`, or `.png`. Such files have to be separated separately. Nevertheless, xcolor offers some basic support by storing the mask color in `\colormask`, which can be used to decide which file is to be included:

```
\def\temp{cyan}\ifx\colormask\temp \includegraphics{foo_c}\else
\def\temp{magenta}\ifx\colormask\temp \includegraphics{foo_m}\else
...
\fi\fi
```

2.9 Color series

Automatic coloring may be useful in graphics or chart applications, where a — potentially large and unspecified — number of colors are needed, and the user does not want or is not able to specify each individual color. Therefore, we introduce the term *color series*, which consists of a base color and a scheme, how the next color is being constructed from the current color.

The practical application consists of three parts: definition of a color series (usually once in the document), initialisation of the series (potentially several times), and application — with or without stepping — of the current color of the series (potentially many times).

2.9.1 Definition of a color series

`\definecolorseries` `{⟨name⟩}{⟨core model⟩}{⟨method⟩}[⟨b-model⟩]{⟨b-spec⟩}[⟨s-model⟩]{⟨s-spec⟩}`
 Defines a color series called `⟨name⟩`, whose calculations are performed within the color model `⟨core model⟩`, where `⟨method⟩` selects the algorithm (one of `step`, `grad`, `last`, see below). The method details are determined by the remaining arguments:

- `[⟨b-model⟩]{⟨b-spec⟩}` specifies the *base* (= first) color in the algorithm, either directly, e.g., `[rgb]{1,0.5,0.5}`, or as a `⟨color⟩`, e.g., `{-yellow!50}`, if the optional argument is missing.
- `[⟨s-model⟩]{⟨s-spec⟩}` specifies how the *step* vector is calculated in the algorithm, according to the chosen `⟨method⟩`:
 - **step, grad**: the optional argument is meaningless, and `⟨s-spec⟩` is a parameter vector whose dimension is determined by `⟨core model⟩`, e.g., `{0.1,-0.2,0.3}` in case of `rgb`, `cmy`, or `hsb`.
 - **last**: the last color is specified either directly, e.g., `[rgb]{1,0.5,0.5}`, or as a `⟨color⟩`, e.g., `{-yellow!50}`, if the optional argument is missing.

This is the general scheme:

$$color_1 := base, \quad color_{n+1} := U(color_n + step) \quad (6)$$

for $n = 1, 2, \dots$, where U maps arbitrary real m -vectors into the unit m -cube:

$$U(x_1, \dots, x_m) = (u(x_1), \dots, u(x_m)), \quad u(x) = \begin{cases} 1 & \text{if } x = 1 \\ x - [x] & \text{if } x \neq 1 \end{cases} \quad (7)$$

Thus, every step of the algorithm yields a valid color with parameters from the interval $[0, 1]$.

Now, the different methods use different schemes to calculate the *step* vector:

- **step, grad**: the last argument, $\{\langle s-spec \rangle\}$, defines the directional vector *grad*.
- **last**: $\{\langle s-spec \rangle\}$ resp. $[\langle s-model \rangle]\{\langle s-spec \rangle\}$ defines the color parameter vector *last*.

Then, during `\resetcolorseries`, the actual *step* vector is calculated:

$$step := \begin{cases} grad & \text{if } \langle method \rangle = \text{step} \\ \frac{1}{\langle div \rangle} \cdot grad & \text{if } \langle method \rangle = \text{grad} \\ \frac{1}{\langle div \rangle} \cdot (last - base) & \text{if } \langle method \rangle = \text{last} \end{cases} \quad (8)$$

Please note that it is also possible to use the current color placeholder ‘.’ within the definition of color series. Thus, `\definecolorseries{foo}{rgb}{last}{.}{-}` will set up a series that starts with the current color and ends with its complement. Of course, similar to T_EX’s `\let` primitive, the *current* definition of the current color at the time of execution is used, there is no relation to current colors in any later stage of the document.

2.9.2 Initialisation of a color series

`\resetcolorseries` $[\langle div \rangle]\{\langle name \rangle\}$

This command has to be applied at least once, in order to make use of the color series $\langle name \rangle$. It resets the current color of the series to the base color and calculates the actual step vector according to the chosen $\langle div \rangle$, a non-zero real number, for the methods **grad** and **last**, see equation (8). If the optional argument is empty, the value stored in the macro `\colorseriescycle` is applied. Its default value is 16, which can be changed by `\def\colorseriescycle{\langle div \rangle}`, applied *before* the xcolor package is loaded (similar to `\rangeRGB` and friends). The optional argument is ignored in case of the **step** method.

`\colorseriescycle`

2.9.3 Application of a color series

There are two ways to display the current color of a color series: any of the *color expressions* in section 2.3 on page 12 used within a `\color`, `\textcolor`, ... command will display this color according to the usual syntax of such expressions. However, in the cases when $\langle postfix \rangle$ equals ‘`!!+`’, `\color{\langle name \rangle!!+}` etc., will not only display the color, but it will also perform a step operation. Thus, the current color of the series will be changed in that case. An expression `\color{\langle name \rangle!![\langle num \rangle]}` enables direct access to an element of a series, where $\langle num \rangle = 0, 1, 2, \dots$, starting with 0 for the base color. See figure 8 on page 34 for a demonstration of different methods.

2.9.4 Differences between colors and color series

Although they behave similar if applied within color expressions, the objects defined by `\definecolor` and `\definecolorseries` are fundamentally different with respect to their scope/availability: like `color`'s original `\definecolor` command, `\definecolor` generates *local* colors, whereas `\definecolorseries` generates *global* objects (otherwise it would not be possible to use the stepping mechanism within tables or graphics conveniently). E.g., if we assume that `bar` is an undefined color, then after saying

```
\begingroup
\definecolorseries{foo}{rgb}{last}{red}{blue}
\resetcolorseries[10]{foo}
\definecolor{bar}{rgb}{.6,.5,.4}
\endgroup
```

commands like `\color{foo}` or `\color{foo!!+}` may be used without restrictions, whereas `\color{bar}` will give an error message. However, it is possible to say `\colorlet{bar}{foo}` or `\colorlet{bar}{foo!!+}` in order to save the current color of a series locally — with or without stepping.

2.10 Border colors for hyperlinks

The `hyperref` package offers all kinds of support for hyperlinks, pdfmarks etc. There are two standard ways to make hyperlinks visible (see the package documentation [14] for additional information on how to set up these features):

- print hyperlinks in a different color than normal text, using the keys *citecolor*, *filecolor*, *linkcolor*, *menucolor*, *pagecolor*, *runcolor*, *urlcolor* with color expressions, e.g., `\hypersetup{urlcolor=-green!50}`;
- display a colored border around hyperlinks, using the keys *citebordercolor*, *filebordercolor*, *linkbordercolor*, *menubordercolor*, *pagebordercolor*, *runbordercolor*, *urlbordercolor* with explicit numerical **rgb** parameter specification, e.g., `\hypersetup{urlbordercolor={1 0.5 0.25}}`.

Obviously, the second method is somewhat inconvenient since it does not allow for color names or even color expressions. Therefore, `xcolor` provides — via the package option `hyperref` — a set of extended keys *xcitebordercolor*, *xfilebordercolor*, *xlinkbordercolor*, *xmenubordercolor*, *xpagebordercolor*, *xrunbordercolor*, *xurlbordercolor* which are being used in conjunction with color expressions, e.g., `\hypersetup{xurlbordercolor=-green!50}`.

Another new key, *xpdfborder*, provides a way to deal with a *dvips*-related problem: for most of the drivers, a setting like `pdfborder={0 0 1}` will determine the width of the border that is drawn around hyperlinks in points. However, in the *dvips* case, the numerical parameters are interpreted in relation to the chosen output resolution for processing the `.dvi` file into a `.ps` file. Unfortunately, at the time when the `.dvi` is constructed, nobody knows if and at which resolution a transformation into `.ps` will take place afterwards. Consequently, any default value for *pdfborder* may be useful or not. Within `hyperref`, the default for *dvips* is `pdfborder={0 0 12}`, which works fine for a resolution of 600 or 1200 dpi, but which produces an invisible border for a resolution of 8000 dpi, as determined by

the command-line switch `-Ppdf`. On the other hand, setting `pdfborder={0 0 80}` works fine for *dvips* at 8000 dpi, but makes a document unportable, since other drivers (or even *dvips* in a low resolution) will draw very thick boxes in that case. This is where the *xpdfborder* key comes in handy: it rescales its arguments for the *dvips* case by a factor 80 (ready for 8000 dpi) and leaves everything unchanged for other drivers. Thus one can say `xpdfborder={0 0 1}` in a driver-independent way.

2.11 Additional color specification in the pstricks world

For *pstricks* users, there are different ways of invoking colors within command option keys:

- `\psset{linecolor=green!50}`
- `\psset{linecolor=[rgb]{0.5,1,0.5}}`
- `\psframebox[linecolor={ [rgb]{0.5,1,0.5}}]{foo}`

Note the additional curly braces in the last case; without them, the optional argument of `\psframebox` would be terminated too early.

`\definecolor` `[ps]{<name>}{<core model-list>}{<code>}`

Stores PostScript *<code>* — that should not contain slash ‘/’ characters — within a color. Example: after `\definecolor[ps]{foo}{rgb}{bar}`, the *pstricks* command `\psline[linecolor=foo]...` inserts ‘`bar setrgbcolor`’ where the linecolor information is required — at least in case of the *dvips* driver. See also *xcolor2.tex* for an illustrative application.

2.12 Color in tables

`\rowcolors` `[<commands>]{<row>}{<odd-row color>}{<even-row color>}`

`\rowcolors*` `[<commands>]{<row>}{<odd-row color>}{<even-row color>}`

One of these commands has to be executed *before* a table starts. *<row>* tells the number of the first row which should be colored according to the *<odd-row color>* and *<even-row color>* scheme. Each of the color arguments may also be left empty (= no color). In the starred version, *<commands>* are ignored in rows with inactive *rowcolors status* (see below), whereas in the non-starred version, *<commands>* are applied to every row of the table. Such optional commands may be `\hline` or `\noalign{<stuff>}`.

`\showrowcolors` The *rowcolors status* is activated (i.e., use coloring scheme) by default and/or
`\hiderowcolors` `\showrowcolors`, it is inactivated (i.e., ignore coloring scheme) by the command
`\rownum` `\hiderowcolors`. The counter `\rownum` may be used within such a table to access

the current row number. An example is given in figure 10 on page 35. These commands require the `table` option (which loads the *colortbl* package).

Note that table coloring may be combined with color series. This method was used to construct the examples in figure 8 on page 34.

2.13 Color information

`\extractcolorspec` `{<color>}{<cmd>}`

Extracts the color specification of *<color>* and puts it into *<cmd>*; equivalent to `\def\cmd{{<model>}{<spec>}}`.

`\extractcolorspecs` $\{\langle color \rangle\}\{\langle model-cmd \rangle\}\{\langle color-cmd \rangle\}$
 Extracts the color specification of $\langle color \rangle$ and puts it into $\langle model-cmd \rangle$ and $\langle color-cmd \rangle$, respectively.

`\tracingcolors` $=\langle int \rangle$
 Controls the amount of information that is written into the log file:

- $\langle int \rangle \leq 0$: no specific color logging.
- $\langle int \rangle \geq 1$: ignored color definitions due to `\providecolor` are logged.
- $\langle int \rangle \geq 2$: multiple (i.e. overwritten) color definitions are logged.
- $\langle int \rangle \geq 3$: every command that defines a color will be logged.
- $\langle int \rangle \geq 4$: every command that sets a color will be logged.

Like TeX's `\tracing...` commands, this command may be used globally (in the document preamble) or locally/block-wise. The package sets `\tracingcolors=0` as default. Remark: since registers are limited and valuable, no counter is wasted for this issue.



Note that whenever a color is used that has been defined via `color`'s `\definecolor` command rather than `xcolor`'s new `\definecolor` and friends, a warning message 'Incompatible color definition' will be issued.¹⁴

2.14 Color conversion

`\convertcolorspec` $\{\langle model \rangle\}\{\langle spec \rangle\}\{\langle target\ model \rangle\}\{\langle cmd \rangle\}$
 Converts a color, given by the $\langle spec \rangle$ in model $\langle model \rangle$, into $\langle target\ model \rangle$ and stores the new color specification in $\langle cmd \rangle$. $\langle target\ model \rangle$ must be of type $\langle num\ model \rangle$, whereas $\langle model \rangle$ may also be 'named', in which case $\langle spec \rangle$ is simply the name of the color.
 Example: `\convertcolorspec{cmyk}{0.81,1,0,0.07}{HTML}\tmp` acts like `\def\tmp{1F00ED}`.

2.15 Problems and solutions

2.15.1 Name clashes between dvipsnames and svgnames

Due to the fixed option processing order (which does not depend on the order how the options were specified in the `\usepackage` command), the `svgnames` colors will always overrule `dvipsnames` colors with identical names. This can lead to undesired results if both options are used together. For instance, *Fuchsia* yields  under the regime of `dvipsnames` and  with respect to `svgnames`. However, there is a simple trick — based on *deferred color definition* — that allows us to use colors from both sets in the desired way:

```
\usepackage[dvipsnames*,svgnames]{xcolor}
\definecolors{Fuchsia}
```

Now all colors from the SVG set are available (except *Fuchsia*) plus *Fuchsia* from the other set.

¹⁴This should not happen since usually there is no reason to load `color` in parallel to `xcolor`.

2.15.2 Page breaks and pdfTeX

Since pdfTeX does not maintain a *color stack* — in contrast to *dvips* — a typical problem is the behaviour of colors in the case of page breaks, as illustrated by the following example:

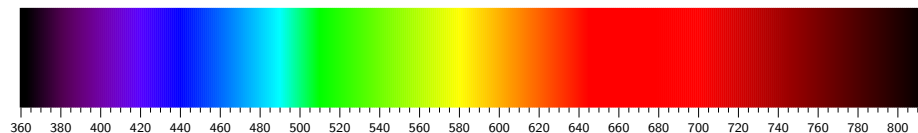
```
\documentclass{minimal}
\usepackage{xcolor}
\begin{document}
black\color{red}red1\newpage red2\color{black}black
\end{document}
```

This works as expected with *dvips*, i.e., ‘red1’ and ‘red2’ being *red*, however, with *pdftex*, ‘red2’ is displayed in *black*. The problem may be solved by using the *fixpdftex* option which simply loads Heiko Oberdiek’s *pdfcolmk* package [13]. However, its author also lists some limitations:

- Mark limitations: page breaks in math.
- LaTeX’s output routine is redefined.
 - Changes in the output routine of newer versions of LaTeX are not detected.
 - Packages that change the output routine are not supported.
- It does not support several independent text streams like footnotes.

3 Examples

Figure 1: Color spectrum

































```

\newcount\WL \unitlength.75pt
\begin{picture}(460,60)(355,-10)
\sffamily \tiny \linethickness{1.25\unitlength} \WL=360
\multiput(360,0)(1,0){456}%
{{\color[wave]{\the\WL}}\line(0,1){50}}\global\advance\WL1}
\linethickness{0.25\unitlength}\WL=360
\multiput(360,0)(20,0){23}%
{\picture(0,0)
\line(0,-1){5} \multiput(5,0)(5,0){3}{\line(0,-1){2.5}}
\put(0,-10){\makebox(0,0){\the\WL}}\global\advance\WL20
\endpicture}
\end{picture}

```

Figure 2: Color testing

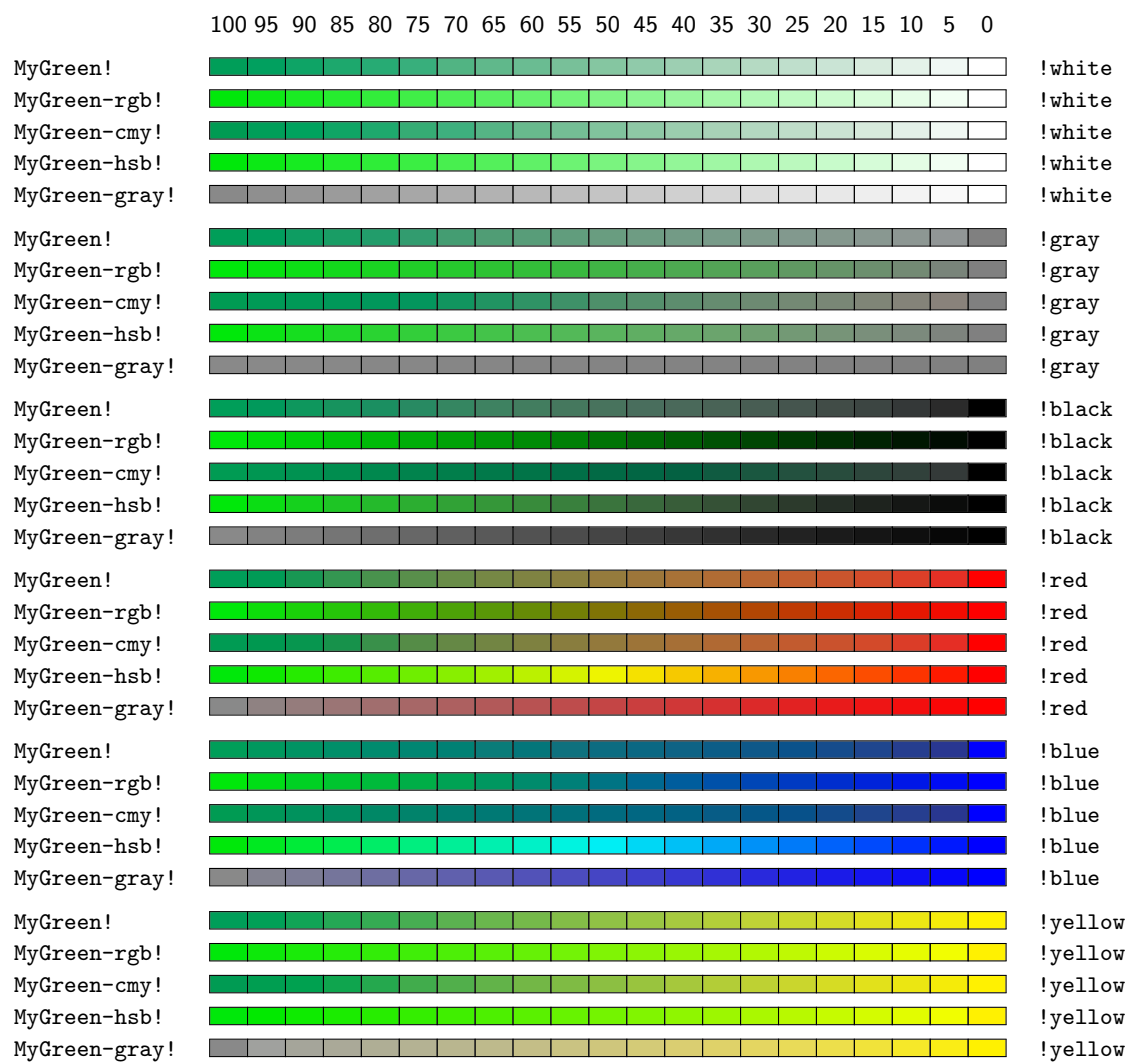
color	rgb	cmk	hsb	HTML	gray
olive	 0.5 0.5 0	 0 0 1 0.5	 0.16667 1 0.5	 808000	 0.39
red!50!green	 0.5 0.5 0	 0 0 0.5 0.5	 0.16667 1 0.5	 808000	 0.445
-cyan!50!magenta	 0.5 0.5 0	 0 0 0.5 0.5	 0.16667 1 0.5	 808000	 0.445
[cmk]0,0,1,0.5	 0.5 0.5 0	 0 0 1 0.5	 0.16667 1 0.5	 808000	 0.39
[cmk]0,0,.5,.5	 0.5 0.5 0	 0 0 0.5 0.5	 0.16667 1 0.5	 808000	 0.445
[rgb:cmk]0,0,.5,.5	 0.5 0.5 0	 0 0 0.5 0.5	 0.16667 1 0.5	 808000	 0.445

```

\sffamily
\begin{testcolors}[rgb,cmk,hsb,HTML,gray]
\testcolor{olive}
\testcolor{red!50!green}
\testcolor{-cyan!50!magenta}
\testcolor[cmk]{0,0,1,0.5}
\testcolor[cmk]{0,0,.5,.5}
\testcolor[rgb:cmk]{0,0,.5,.5}
\end{testcolors}

```

Figure 3: Progressing from one to another color



Color	Definition/representation (dvips driver)
MyGreen	{cmyk 0.92 0 0.87 0.09}{cmyk}{0.92,0,0.87,0.09}
MyGreen-rgb	{rgb 0 0.91 0.04001}{rgb}{0,0.91,0.04001}
MyGreen-cmy	{cmyk 1 0.09 0.95999 0}{cmy}{1,0.09,0.95999}
MyGreen-hsb	{hsb 0.34065 1 0.91}{hsb}{0.34065,1,0.91}
MyGreen-gray	{gray 0.5383}{gray}{0.5383}

Figure 4: Target color model







<code>\selectcolormodel</code>	
<code>...{natural}</code>	
<code>...{rgb}</code>	
<code>...{cmy}</code>	
<code>...{cmyk}</code>	
<code>...{hsb}</code>	
<code>...{gray}</code>	

Figure 5: Standard color expressions















	red		-red
	red!75		-red!75
	red!75!green		-red!75!green
	red!75!green!50		-red!75!green!50
	red!75!green!50!blue		-red!75!green!50!blue
	red!75!green!50!blue!25		-red!75!green!50!blue!25
	red!75!green!50!blue!25!gray		-red!75!green!50!blue!25!gray

Figure 6: Standard color expressions

```

\fbboxrule6pt
\fcolorbox
{red!70!green}% outer frame
{yellow!30!blue}% outer background
{\fcolorbox
{-yellow!30!blue}% inner frame
{-red!70!green}% inner background
{Test\textcolor{red!72.75}{Test}\color{-green}Test}}

```



Figure 7: Current color

```

\def\test{current, \textcolor{.!50}{50\%},
\textcolor{-}{complement},
\textcolor{yellow!50!.}{mix}}
\textcolor{blue}{\test}\
and \textcolor{red}{\test}\
\def\Test{\color{.!80}Test}
\textcolor{blue}{\Test\Test\Test\Test\Test}\
and \textcolor{red}{\Test\Test\Test\Test\Test}

```

current, 50%, complement, mix
and current, 50%, complement, mix
TestTestTestTestTest
and TestTestTestTestTest

Figure 8: Color series

S_1	S_2	G_1	G_2	L_1	L_2	L_3	L_4	L_5
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10
11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12
13	13	13	13	13	13		13	13
14	14	14	14	14	14	14	14	14
15	15	15	15	15	15	15	15	15
16	16	16	16	16	16	16	16	16

<i>Individual definitions</i>	
S_1	<code>\definecolorseries{test}{rgb}{step}[rgb]{.95,.85,.55}{.17,.47,.37}</code>
S_2	<code>\definecolorseries{test}{hsb}{step}[hsb]{.575,1,1}{.11,-.05,0}</code>
G_1	<code>\definecolorseries{test}{rgb}{grad}[rgb]{.95,.85,.55}{3,11,17}</code>
G_2	<code>\definecolorseries{test}{hsb}{grad}[hsb]{.575,1,1}{.987,-.234,0}</code>
L_1	<code>\definecolorseries{test}{rgb}{last}[rgb]{.95,.85,.55}[rgb]{.05,.15,.55}</code>
L_2	<code>\definecolorseries{test}{hsb}{last}[hsb]{.575,1,1}[hsb]{-.425,.15,1}</code>
L_3	<code>\definecolorseries{test}{rgb}{last}{yellow!50}{blue}</code>
L_4	<code>\definecolorseries{test}{hsb}{last}{yellow!50}{blue}</code>
L_5	<code>\definecolorseries{test}{cmy}{last}{yellow!50}{blue}</code>
<i>Common definitions</i>	
<code>\resetcolorseries[12]{test}</code>	
<code>\rowcolors[\hline]{1}{test!!+}{test!!+}</code>	
<code>\begin{tabular}{c}</code>	
<code>\number\rownum\ \number\rownum\ \number\rownum\ \number\rownum\</code>	
<code>\number\rownum\ \number\rownum\ \number\rownum\ \number\rownum\</code>	
<code>\number\rownum\ \number\rownum\ \number\rownum\ \number\rownum\</code>	
<code>\number\rownum\ \number\rownum\ \number\rownum\ \number\rownum\</code>	
<code>\end{tabular}</code>	

Figure 9: Color masking

































































































































































































































































\maskcolors																
...{}																
...[cmyk]{cyan}																
...[cmyk]{magenta}																
...[cmyk]{yellow}																
...[cmyk]{black}																
...[cmyk]{red}																
...[cmyk]{green}																
...[cmyk]{blue}																
...[rgb]{red}																
...[rgb]{green}																
...[rgb]{blue}																
...[hsb]{red}																
...[hsb]{green}																
...[hsb]{blue}																
...[rgb]{gray}																
...[cmy]{gray}																

Figure 10: Alternating row colors in tables: \rowcolors vs. \rowcolors*

\rowcolors[\hline]{3}{green!25}{yellow!50} \arrayrulecolor{red!75!gray}		
\begin{tabular}{ll}		
test & row \number\rownum\\	test row 1	test row 1
test & row \number\rownum\\	test row 2	test row 2
test & row \number\rownum\\	test row 3	test row 3
test & row \number\rownum\\	test row 4	test row 4
\arrayrulecolor{black}		
test & row \number\rownum\\	test row 5	test row 5
test & row \number\rownum\\	test row 6	test row 6
\rowcolor{blue!25}		
test & row \number\rownum\\	test row 7	test row 7
test & row \number\rownum\\	test row 8	test row 8
\hiderowcolors		
test & row \number\rownum\\	test row 9	test row 9
test & row \number\rownum\\	test row 10	test row 10
\showrowcolors		
test & row \number\rownum\\	test row 11	test row 11
test & row \number\rownum\\	test row 12	test row 12
\multicolumn{1}{%}	test row 13	test row 13
{>\columncolor{red!12}}1}{test} & row \number\rownum\\		
\end{tabular}		

Figure 11: **Hsb** and **tHsb**: *hue*° in 15° steps















































































































































































































































































































































































color	rgb	cmYk	hsb	Hsb	tHsb
[Hsb]0,1,1	 1 0 0	 0 1 1 0	 0 1 1	 0 1 1	 0 1 1
[Hsb]15,1,1	 1 0.25002 0	 0 0.74998 1 0	 0.04167 1 1	 15.00128 1 1	 30.00256 1 1
[Hsb]30,1,1	 1 0.49998 0	 0 0.50002 1 0	 0.08333 1 1	 29.99872 1 1	 59.99744 1 1
[Hsb]45,1,1	 1 0.75 0	 0 0.25 1 0	 0.125 1 1	 45 1 1	 90 1 1
[Hsb]60,1,1	 0.99998 1 0	 0.00002 0 1 0	 0.16667 1 1	 60.00128 1 1	 120.00128 1 1
[Hsb]75,1,1	 0.75002 1 0	 0.24998 0 1 0	 0.20833 1 1	 74.99872 1 1	 134.99872 1 1
[Hsb]90,1,1	 0.5 1 0	 0.5 0 1 0	 0.25 1 1	 90 1 1	 150 1 1
[Hsb]105,1,1	 0.24998 1 0	 0.75002 0 1 0	 0.29167 1 1	 105.00128 1 1	 165.00128 1 1
[Hsb]120,1,1	 0.00002 1 0	 0.99998 0 1 0	 0.33333 1 1	 119.99872 1 1	 179.99872 1 1
[Hsb]135,1,1	 0 1 0.25	 1 0 0.75 0	 0.375 1 1	 135 1 1	 187.5 1 1
[Hsb]150,1,1	 0 1 0.50002	 1 0 0.49998 0	 0.41667 1 1	 150.00128 1 1	 195.00064 1 1
[Hsb]165,1,1	 0 1 0.74998	 1 0 0.25002 0	 0.45833 1 1	 164.99872 1 1	 202.49936 1 1
[Hsb]180,1,1	 0 1 1	 1 0 0 0	 0.5 1 1	 180 1 1	 210 1 1
[Hsb]195,1,1	 0 0.74998 1	 1 0.25002 0 0	 0.54167 1 1	 195.00128 1 1	 217.50064 1 1
[Hsb]210,1,1	 0 0.50002 1	 1 0.49998 0 0	 0.58333 1 1	 209.99872 1 1	 224.99936 1 1
[Hsb]225,1,1	 0 0.25 1	 1 0.75 0 0	 0.625 1 1	 225 1 1	 232.5 1 1
[Hsb]240,1,1	 0.00002 0 1	 0.99998 1 0 0	 0.66667 1 1	 240.00128 1 1	 240.00128 1 1
[Hsb]255,1,1	 0.24998 0 1	 0.75002 1 0 0	 0.70833 1 1	 254.99872 1 1	 254.99872 1 1
[Hsb]270,1,1	 0.5 0 1	 0.5 1 0 0	 0.75 1 1	 270 1 1	 270 1 1
[Hsb]285,1,1	 0.75002 0 1	 0.24998 1 0 0	 0.79167 1 1	 285.00128 1 1	 285.00128 1 1
[Hsb]300,1,1	 0.99998 0 1	 0.00002 1 0 0	 0.83333 1 1	 299.99872 1 1	 299.99872 1 1
[Hsb]315,1,1	 1 0 0.75	 0 1 0.25 0	 0.875 1 1	 315 1 1	 315 1 1
[Hsb]330,1,1	 1 0 0.49998	 0 1 0.50002 0	 0.91667 1 1	 330.00128 1 1	 330.00128 1 1
[Hsb]345,1,1	 1 0 0.25002	 0 1 0.74998 0	 0.95833 1 1	 344.99872 1 1	 344.99872 1 1
[Hsb]360,1,1	 1 0 0	 0 1 1 0	 1 1 1	 360 1 1	 360 1 1
[tHsb]0,1,1	 1 0 0	 0 1 1 0	 0 1 1	 0 1 1	 0 1 1
[tHsb]15,1,1	 1 0.12498 0	 0 0.87502 1 0	 0.02083 1 1	 7.49872 1 1	 14.99744 1 1
[tHsb]30,1,1	 1 0.25002 0	 0 0.74998 1 0	 0.04167 1 1	 15.00128 1 1	 30.00256 1 1
[tHsb]45,1,1	 1 0.375 0	 0 0.625 1 0	 0.0625 1 1	 22.5 1 1	 45 1 1
[tHsb]60,1,1	 1 0.49998 0	 0 0.50002 1 0	 0.08333 1 1	 29.99872 1 1	 59.99744 1 1
[tHsb]75,1,1	 1 0.62502 0	 0 0.37498 1 0	 0.10417 1 1	 37.50128 1 1	 75.00256 1 1
[tHsb]90,1,1	 1 0.75 0	 0 0.25 1 0	 0.125 1 1	 45 1 1	 90 1 1
[tHsb]105,1,1	 1 0.87498 0	 0 0.12502 1 0	 0.14583 1 1	 52.49872 1 1	 104.99744 1 1
[tHsb]120,1,1	 0.99998 1 0	 0.00002 0 1 0	 0.16667 1 1	 60.00128 1 1	 120.00128 1 1
[tHsb]135,1,1	 0.75002 1 0	 0.24998 0 1 0	 0.20833 1 1	 74.99872 1 1	 134.99872 1 1
[tHsb]150,1,1	 0.5 1 0	 0.5 0 1 0	 0.25 1 1	 90 1 1	 150 1 1
[tHsb]165,1,1	 0.24998 1 0	 0.75002 0 1 0	 0.29167 1 1	 105.00128 1 1	 165.00128 1 1
[tHsb]180,1,1	 0.00002 1 0	 0.99998 0 1 0	 0.33333 1 1	 119.99872 1 1	 179.99872 1 1
[tHsb]195,1,1	 0 1 0.50002	 1 0 0.49998 0	 0.41667 1 1	 150.00128 1 1	 195.00064 1 1
[tHsb]210,1,1	 0 1 1	 1 0 0 0	 0.5 1 1	 180 1 1	 210 1 1
[tHsb]225,1,1	 0 0.50002 1	 1 0.49998 0 0	 0.58333 1 1	 209.99872 1 1	 224.99936 1 1
[tHsb]240,1,1	 0.00002 0 1	 0.99998 1 0 0	 0.66667 1 1	 240.00128 1 1	 240.00128 1 1
[tHsb]255,1,1	 0.24998 0 1	 0.75002 1 0 0	 0.70833 1 1	 254.99872 1 1	 254.99872 1 1
[tHsb]270,1,1	 0.5 0 1	 0.5 1 0 0	 0.75 1 1	 270 1 1	 270 1 1
[tHsb]285,1,1	 0.75002 0 1	 0.24998 1 0 0	 0.79167 1 1	 285.00128 1 1	 285.00128 1 1
[tHsb]300,1,1	 0.99998 0 1	 0.00002 1 0 0	 0.83333 1 1	 299.99872 1 1	 299.99872 1 1
[tHsb]315,1,1	 1 0 0.75	 0 1 0.25 0	 0.875 1 1	 315 1 1	 315 1 1
[tHsb]330,1,1	 1 0 0.49998	 0 1 0.50002 0	 0.91667 1 1	 330.00128 1 1	 330.00128 1 1
[tHsb]345,1,1	 1 0 0.25002	 0 1 0.74998 0	 0.95833 1 1	 344.99872 1 1	 344.99872 1 1
[tHsb]360,1,1	 1 0 0	 0 1 1 0	 1 1 1	 360 1 1	 360 1 1

Figure 12: Color harmony

color	rgb	cmYk	Hsb	tHsb
<i>complementary colors (two-color harmony):</i>				
yellow>wheel,1,2	 0.00002 0 1	 0.99998 1 0 0	 240.00128 1 1	 240.00128 1 1
yellow	 1 1 0	 0 0 1 0	 60.00128 1 1	 120.00128 1 1
yellow>twheel,1,2	 1 0 0.99995	 0 1 0.00005 0	 300.00256 1 1	 300.00256 1 1
<i>color triad (three-color harmony):</i>				
yellow>wheel,2,3	 1 0 0.99995	 0 1 0.00005 0	 300.00256 1 1	 300.00256 1 1
yellow>wheel,1,3	 0 1 1	 1 0 0 0	 180 1 1	 210 1 1
yellow	 1 1 0	 0 0 1 0	 60.00128 1 1	 120.00128 1 1
yellow>twheel,1,3	 0.00002 0 1	 0.99998 1 0 0	 240.00128 1 1	 240.00128 1 1
yellow>twheel,2,3	 1 0.00012 0	 0 0.99988 1 0	 0.00714 1 1	 0.01428 1 1
<i>color tetrad (four-color harmony):</i>				
yellow>wheel,3,4	 1 0 0.49998	 0 1 0.50002 0	 330.00128 1 1	 330.00128 1 1
yellow>wheel,2,4	 0.00002 0 1	 0.99998 1 0 0	 240.00128 1 1	 240.00128 1 1
yellow>wheel,1,4	 0 1 0.50002	 1 0 0.49998 0	 150.00128 1 1	 195.00064 1 1
yellow	 1 1 0	 0 0 1 0	 60.00128 1 1	 120.00128 1 1
yellow>twheel,1,4	 0 0.99988 1	 1 0.00012 0 0	 180.00714 1 1	 210.00357 1 1
yellow>twheel,2,4	 1 0 0.99995	 0 1 0.00005 0	 300.00256 1 1	 300.00256 1 1
yellow>twheel,3,4	 1 0.25002 0	 0 0.74998 1 0	 15.00128 1 1	 30.00256 1 1
<i>split complementary colors:</i>				
yellow>wheel,7,12	 0.5 0 1	 0.5 1 0 0	 270 1 1	 270 1 1
yellow>wheel,5,12	 0 0.49995 1	 1 0.50005 0 0	 210.00256 1 1	 225.00128 1 1
yellow	 1 1 0	 0 0 1 0	 60.00128 1 1	 120.00128 1 1
yellow>twheel,5,12	 0.50018 0 1	 0.49982 1 0 0	 270.01099 1 1	 270.01099 1 1
yellow>twheel,7,12	 1 0 0.49998	 0 1 0.50002 0	 330.00128 1 1	 330.00128 1 1
<i>analogous (adjacent) colors:</i>				
yellow>wheel,11,12	 1 0.50005 0	 0 0.49995 1 0	 30.00256 1 1	 60.00513 1 1
yellow>wheel,10,12	 1 0 0	 0 1 1 0	 360 1 1	 360 1 1
yellow>wheel,2,12	 0 1 0.00005	 1 0 0.99995 0	 120.00256 1 1	 180.00128 1 1
yellow>wheel,1,12	 0.5 1 0	 0.5 0 1 0	 90 1 1	 150 1 1
yellow	 1 1 0	 0 0 1 0	 60.00128 1 1	 120.00128 1 1
yellow>twheel,1,12	 0.5 1 0	 0.5 0 1 0	 90 1 1	 150 1 1
yellow>twheel,2,12	 0 1 0.00021	 1 0 0.99979 0	 120.013 1 1	 180.0065 1 1
yellow>twheel,10,12	 1 0.50005 0	 0 0.49995 1 0	 30.00256 1 1	 60.00513 1 1
yellow>twheel,11,12	 1 0.75012 0	 0 0.24988 1 0	 45.00714 1 1	 90.01428 1 1

4 Colors by Name

4.1 Base Colors





































 black	 darkgray	 magenta	 purple	 yellow
 blue	 gray	 olive	 red	
 brown	 green	 orange	 violet	
 cyan	 lightgray	 pink	 white	

4.2 Colors via dvipsnames

 Apricot	 Cyan	 Mahogany	 ProcessBlue	 SpringGreen
 Aquamarine	 Dandelion	 Maroon	 Purple	 Tan
 Bittersweet	 DarkOrchid	 Melon	 RawSienna	 TealBlue
 Black	 Emerald	 MidnightBlue	 Red	 Thistle
 Blue	 ForestGreen	 Mulberry	 RedOrange	 Turquoise
 BlueGreen	 Fuchsia	 NavyBlue	 RedViolet	 Violet
 BlueViolet	 Goldenrod	 OliveGreen	 Rhodamine	 VioletRed
 BrickRed	 Gray	 Orange	 RoyalBlue	 White
 Brown	 Green	 OrangeRed	 RoyalPurple	 WildStrawberry
 BurntOrange	 GreenYellow	 Orchid	 RubineRed	 Yellow
 CadetBlue	 JungleGreen	 Peach	 Salmon	 YellowGreen
 CarnationPink	 Lavender	 Periwinkle	 SeaGreen	 YellowOrange
 Cerulean	 LimeGreen	 PineGreen	 Sepia	
 CornflowerBlue	 Magenta	 Plum	 SkyBlue	

4.3 Colors via svgnames

































































































































































 AliceBlue	 DarkKhaki	 Green	 LightSlateGrey
 AntiqueWhite	 DarkMagenta	 GreenYellow	 LightSteelBlue
 Aqua	 DarkOliveGreen	 Grey	 LightYellow
 Aquamarine	 DarkOrange	 Honeydew	 Lime
 Azure	 DarkOrchid	 HotPink	 LimeGreen
 Beige	 DarkRed	 IndianRed	 Linen
 Bisque	 DarkSalmon	 Indigo	 Magenta
 Black	 DarkSeaGreen	 Ivory	 Maroon
 BlanchedAlmond	 DarkSlateBlue	 Khaki	 MediumAquamarine
 Blue	 DarkSlateGray	 Lavender	 MediumBlue
 BlueViolet	 DarkTurquoise	 LavenderBlush	 MediumOrchid
 Brown	 DarkViolet	 LawnGreen	 MediumPurple
 BurlyWood	 DeepPink	 LemonChiffon	 MediumSeaGreen
 CadetBlue	 DeepSkyBlue	 LightBlue	 MediumSlateBlue
 Chartreuse	 DimGray	 LightCoral	 MediumSpringGreen
 Chocolate	 DimGrey	 LightCyan	 MediumTurquoise
 Coral	 DodgerBlue	 LightGoldenrod	 MediumVioletRed
 CornflowerBlue	 FireBrick	 LightGoldenrodYellow	 MidnightBlue
 Cornsilk	 FloralWhite	 LightGray	 MintCream
 Crimson	 ForestGreen	 LightGreen	 MistyRose
 Cyan	 Fuchsia	 LightGrey	 Moccasin
 DarkBlue	 Gainsboro	 LightPink	 NavajoWhite
 DarkCyan	 Ghost White	 LightSalmon	 Navy
 DarkGoldenrod	 Gold	 LightSeaGreen	 NavyBlue
 DarkGray	 Goldenrod	 LightSkyBlue	 OldLace
 DarkGreen	 Gray	 LightSlateBlue	 Olive
 DarkGrey		 LightSlateGray	 OliveDrab




























































































































































 Orange	 Plum	 Sienna	 Thistle
 OrangeRed	 PowderBlue	 Silver	 Tomato
 Orchid	 Purple	 SkyBlue	 Turquoise
 PaleGoldenrod	 Red	 SlateBlue	 Violet
 PaleGreen	 RosyBrown	 SlateGray	 VioletRed
 PaleTurquoise	 RoyalBlue	 SlateGrey	 Wheat
 PaleVioletRed	 SaddleBrown	 Snow	 White
 PapayaWhip	 Salmon	 SpringGreen	 WhiteSmoke
 PeachPuff	 SandyBrown	 SteelBlue	 Yellow
 Peru	 SeaGreen	 Tan	 YellowGreen
 Pink	 Seashell	 Teal	

Duplicate colors: Aqua = Cyan, Fuchsia = Magenta; Navy = NavyBlue; Gray = Grey, DarkGray = DarkGrey, LightGray = LightGrey, SlateGray = SlateGrey, DarkSlateGray = DarkSlateGrey, LightSlateGray = LightSlateGrey, DimGray = DimGrey.

Colors taken from Unix/X11: LightGoldenrod, LightSlateBlue, NavyBlue, VioletRed.

4.4 Colors via x11names

 AntiqueWhite1	 Coral1	 DeepSkyBlue1	 Khaki1
 AntiqueWhite2	 Coral2	 DeepSkyBlue2	 Khaki2
 AntiqueWhite3	 Coral3	 DeepSkyBlue3	 Khaki3
 AntiqueWhite4	 Coral4	 DeepSkyBlue4	 Khaki4
 Aquamarine1	 Cornsilk1	 DodgerBlue1	 LavenderBlush1
 Aquamarine2	 Cornsilk2	 DodgerBlue2	 LavenderBlush2
 Aquamarine3	 Cornsilk3	 DodgerBlue3	 LavenderBlush3
 Aquamarine4	 Cornsilk4	 DodgerBlue4	 LavenderBlush4
 Azure1	 Cyan1	 Firebrick1	 LemonChiffon1
 Azure2	 Cyan2	 Firebrick2	 LemonChiffon2
 Azure3	 Cyan3	 Firebrick3	 LemonChiffon3
 Azure4	 Cyan4	 Firebrick4	 LemonChiffon4
 Bisque1	 DarkGoldenrod1	 Gold1	 LightBlue1
 Bisque2	 DarkGoldenrod2	 Gold2	 LightBlue2
 Bisque3	 DarkGoldenrod3	 Gold3	 LightBlue3
 Bisque4	 DarkGoldenrod4	 Gold4	 LightBlue4
 Blue1	 DarkOliveGreen1	 Goldenrod1	 LightCyan1
 Blue2	 DarkOliveGreen2	 Goldenrod2	 LightCyan2
 Blue3	 DarkOliveGreen3	 Goldenrod3	 LightCyan3
 Blue4	 DarkOliveGreen4	 Goldenrod4	 LightCyan4
 Brown1	 DarkOrange1	 Green1	 LightGoldenrod1
 Brown2	 DarkOrange2	 Green2	 LightGoldenrod2
 Brown3	 DarkOrange3	 Green3	 LightGoldenrod3
 Brown4	 DarkOrange4	 Green4	 LightGoldenrod4
 Burlywood1	 DarkOrchid1	 Honeydew1	 LightPink1
 Burlywood2	 DarkOrchid2	 Honeydew2	 LightPink2
 Burlywood3	 DarkOrchid3	 Honeydew3	 LightPink3
 Burlywood4	 DarkOrchid4	 Honeydew4	 LightPink4
 CadetBlue1	 DarkSeaGreen1	 HotPink1	 LightSalmon1
 CadetBlue2	 DarkSeaGreen2	 HotPink2	 LightSalmon2
 CadetBlue3	 DarkSeaGreen3	 HotPink3	 LightSalmon3
 CadetBlue4	 DarkSeaGreen4	 HotPink4	 LightSalmon4
 Chartreuse1	 DarkSlateGray1	 IndianRed1	 LightSkyBlue1
 Chartreuse2	 DarkSlateGray2	 IndianRed2	 LightSkyBlue2
 Chartreuse3	 DarkSlateGray3	 IndianRed3	 LightSkyBlue3
 Chartreuse4	 DarkSlateGray4	 IndianRed4	 LightSkyBlue4
 Chocolate1	 DeepPink1	 Ivory1	 LightSteelBlue1
 Chocolate2	 DeepPink2	 Ivory2	 LightSteelBlue2
 Chocolate3	 DeepPink3	 Ivory3	 LightSteelBlue3
 Chocolate4	 DeepPink4	 Ivory4	 LightSteelBlue4

 Light Yellow1	 Orchid1	 RoyalBlue1	 SteelBlue1
 Light Yellow2	 Orchid2	 RoyalBlue2	 SteelBlue2
 Light Yellow3	 Orchid3	 RoyalBlue3	 SteelBlue3
 Light Yellow4	 Orchid4	 RoyalBlue4	 SteelBlue4
 Magenta1	 PaleGreen1	 Salmon1	 Tan1
 Magenta2	 PaleGreen2	 Salmon2	 Tan2
 Magenta3	 PaleGreen3	 Salmon3	 Tan3
 Magenta4	 PaleGreen4	 Salmon4	 Tan4
 Maroon1	 PaleTurquoise1	 SeaGreen1	 Thistle1
 Maroon2	 PaleTurquoise2	 SeaGreen2	 Thistle2
 Maroon3	 PaleTurquoise3	 SeaGreen3	 Thistle3
 Maroon4	 PaleTurquoise4	 SeaGreen4	 Thistle4
 MediumOrchid1	 PaleVioletRed1	 Seashell1	 Tomato1
 MediumOrchid2	 PaleVioletRed2	 Seashell2	 Tomato2
 MediumOrchid3	 PaleVioletRed3	 Seashell3	 Tomato3
 MediumOrchid4	 PaleVioletRed4	 Seashell4	 Tomato4
 MediumPurple1	 PeachPuff1	 Sienna1	 Turquoise1
 MediumPurple2	 PeachPuff2	 Sienna2	 Turquoise2
 MediumPurple3	 PeachPuff3	 Sienna3	 Turquoise3
 MediumPurple4	 PeachPuff4	 Sienna4	 Turquoise4
 MistyRose1	 Pink1	 SkyBlue1	 VioletRed1
 MistyRose2	 Pink2	 SkyBlue2	 VioletRed2
 MistyRose3	 Pink3	 SkyBlue3	 VioletRed3
 MistyRose4	 Pink4	 SkyBlue4	 VioletRed4
 NavajoWhite1	 Plum1	 SlateBlue1	 Wheat1
 NavajoWhite2	 Plum2	 SlateBlue2	 Wheat2
 NavajoWhite3	 Plum3	 SlateBlue3	 Wheat3
 NavajoWhite4	 Plum4	 SlateBlue4	 Wheat4
 OliveDrab1	 Purple1	 SlateGray1	 Yellow1
 OliveDrab2	 Purple2	 SlateGray2	 Yellow2
 OliveDrab3	 Purple3	 SlateGray3	 Yellow3
 OliveDrab4	 Purple4	 SlateGray4	 Yellow4
 Orange1	 Red1	 Snow1	 Gray0
 Orange2	 Red2	 Snow2	 Green0
 Orange3	 Red3	 Snow3	 Grey0
 Orange4	 Red4	 Snow4	 Maroon0
 OrangeRed1	 RosyBrown1	 SpringGreen1	 Purple0
 OrangeRed2	 RosyBrown2	 SpringGreen2	
 OrangeRed3	 RosyBrown3	 SpringGreen3	
 OrangeRed4	 RosyBrown4	 SpringGreen4	

Duplicate colors: Gray0 = Grey0, Green0 = Green1.

5 Technical Supplement

5.1 Color models supported by drivers

Since some of the drivers only pretend to support the **hsb** model, we included some code to bypass this behaviour. The models actually added by **xcolor** are shown in the log file. Table 5 lists mainly the drivers that are part of current MiKTeX [11] distributions and their color model support. Probably, other distributions behave similarly.

Table 5: Drivers and color models

<i>Driver</i>	<i>Version</i>	rgb	cm	my	cm	yk	hsb	gray	RGB	HTML	HSB	Gray
dvipdf	1999/02/16 v3.0i	d	n	d	n	d	n	d	i	n	n	n
dvips	1999/02/16 v3.0i	d	n	d	d	d	d	d	i	n	n	n
dvipsone	1999/02/16 v3.0i	d	n	d	d	d	d	d	i	n	n	n
pctex32	1999/02/16 v3.0i	d	n	d	d	d	d	d	i	n	n	n
pctexps	1999/02/16 v3.0i	d	n	d	d	d	d	d	i	n	n	n
pdftex	2002/06/19 v0.03k	d	n	d	n	d	n	d	i	n	n	n
dvipdfm	1998/11/24 vx.x ¹	d	n	d	a	d	i	n	n	n	n	n
dvipdfm	1999/9/6 vx.x ²	d	n	d	a	d	i	n	n	n	n	n
dvipdfmx	?	d	n	d	f	d	i	n	n	n	n	n
textures	1997/5/28 v0.3	d	n	d	a	i	n	n	n	n	n	n
vtex	1999/01/14 v6.3	d	n	d	n	i	i	n	n	n	n	n
xetex	2004/05/09 v0.7	i	n	i	i	i	i	d	n	n	n	n
tcidvi	1999/02/16 v3.0i	i	n	i	n	i	d	n	n	n	n	n
truetex	1999/02/16 v3.0i	i	n	i	n	i	d	n	n	n	n	n
dviwin	1999/02/16 v3.0i	n	n	n	n	n	n	n	n	n	n	n
emtex	1999/02/16 v3.0i	n	n	n	n	n	n	n	n	n	n	n
pctexhp	1999/02/16 v3.0i	n	n	n	n	n	n	n	n	n	n	n
pctexwin	1999/02/16 v3.0i	n	n	n	n	n	n	n	n	n	n	n

dviwindo = dvipsone; oztex = dvips; xdvi = dvips + monochrome

¹ part of **graphics** package ² additionally distributed with MiKTeX

Driver's color model support: d = direct, i = indirect, a = alleged, n = none, f = faulty

5.2 How **xcolor** handles driver-specific color models

Although there is a variety of drivers that implement different approaches to color visualisation, they all have some features in common, as defined by the original color package. One of these features is that any color model ‘foo’ requires a `\color@foo{<cmd>}{<spec>}` command in order to translate the ‘foo’-dependent color `<spec>` into some driver-specific code that is stored in `<cmd>`. Therefore, **xcolor** in general detects driver-support for the ‘foo’ model via the existence of `\color@foo`.

By this mechanism, **xcolor** can also change the behaviour of certain models without touching the driver file itself. A good example is the `\substitutecolormodel` command which is used during the package initialisation process to provide support for models that are not covered by the actual driver (like **hsb** for **pdftex**) or

that have incorrect implementations (like **hsb** for **dvipdfm**).

5.3 Behind the scenes: internal color representation

Every definition of a color in order to access it by its name requires an internal representation of the color, i.e. a macro that contains some bits of information required by the driver to display the color properly.

color's `\definecolor{foo}{...}{...}` generates a command `\color@foo`¹⁵ which contains the color definition in a driver-dependent way; therefore it is possible but non-trivial to access the color model and parameters afterwards (see the `colorinfo` package [12] for a solution).

color's `\DefineNamedColor{named}{foo}{...}{...}` generates `\col@foo`¹⁶ which again contains some driver-dependent information. In this case, an additional `\color@foo` will only be defined if the package option `usecolors` is active.

xcolor's `\definecolor{foo}{...}{...}` generates¹⁷ a command `\color@foo` as well, which combines the features of the former commands and contains both the driver-dependent and driver-independent information, thus making it possible to access the relevant parameters in a standardised way. Although it has now a different syntax, `\color@foo` expands to the same expression as the original command. On the other hand, `\col@foo` commands are no longer needed and therefore not generated in the 'named' case: xcolor works with a single color data structure (as described).

Table 6 on the following page shows some examples for the two most prominent drivers. See also figure 3 on page 32 which displays the definitions with respect to the driver that was used to process this document.

5.4 A remark on accuracy

Since the macros presented here require some computation, special efforts were made to ensure a maximum of accuracy for conversion and mixing formulas — all within T_EX's limited numerical capabilities.¹⁸ We decided to develop and include a small set of commands to improve the quality of division and multiplication results, instead of loading one of the packages that provide multi-digit arithmetic and a lot more, like `realcalc` or `fp`. The marginal contribution of the latter packages seems not to justify their usage for our purposes. Thus, we stay within a sort of fixed-point arithmetic framework, providing at most 5 decimal digits via T_EX's dimension registers.

¹⁵The double backslash is intentional.

¹⁶The single backslash is intentional.

¹⁷This was introduced in version 1.10; prior to that, a command `\xcolor@foo` with a different syntax was generated.

¹⁸For example, applying the 'transformation' `\dimen0=0.<int>pt \the\dimen0` to all 5-digit numbers $\langle int \rangle$ of the range 00000...99999, exactly 34464 of these 100000 numbers don't survive unchanged. We are not talking about gobbled final zeros here ...

Table 6: Driver-dependent internal color representation

dvips driver		
<code>\color@Plum=macro:</code>	<code>(\definecolor{Plum}{rgb}{.5,0,1})</code>	color
<code>->rgb .5 0 1.</code>		
<code>\color@Plum=macro:</code>	<code>(\definecolor{Plum}{rgb}{.5,0,1})</code>	xcolor
<code>->\xcolor@ {}{rgb 0.5 0 1}{rgb}{0.5,0,1}.</code>		
<code>\col@Plum=macro:</code>	<code>(\DefineNamedColor{Plum}{rgb}{.5,0,1})</code>	color
<code>->\@nil .</code>		
<code>\color@Plum=macro:</code>	<code>(with option usenames)</code>	
<code>-> Plum.</code>		
<code>\color@Plum=macro:</code>	<code>(\definecolor[named]{Plum}{rgb}{.5,0,1})</code>	xcolor
<code>->\xcolor@ {named}{ Plum}{rgb}{0.5,0,1}.</code>		
pdftex driver		
<code>\color@Plum=macro:</code>	<code>(\definecolor{Plum}{rgb}{.5,0,1})</code>	color
<code>->.5 0 1 rg .5 0 1 RG.</code>		
<code>\color@Plum=macro:</code>	<code>(\definecolor{Plum}{rgb}{.5,0,1})</code>	xcolor
<code>->\xcolor@ {}{0.5 0 1 rg 0.5 0 1 RG}{rgb}{0.5,0,1}.</code>		
<code>\col@Plum=macro:</code>	<code>(\DefineNamedColor{Plum}{rgb}{.5,0,1})</code>	color
<code>->.5 0 1 rg .5 0 1 RG.</code>		
<code>\color@Plum=macro:</code>	<code>(with option usenames)</code>	
<code>->.5 0 1 rg .5 0 1 RG.</code>		
<code>\color@Plum=macro:</code>	<code>(\definecolor[named]{Plum}{rgb}{.5,0,1})</code>	xcolor
<code>->\xcolor@ {}{0.5 0 1 rg 0.5 0 1 RG}{rgb}{0.5,0,1}.</code>		

6 The Formulas

6.1 Color mixing

In general, we use linear interpolation for color mixing:

$$\text{mix}(C, C', p) = p \cdot C + (1 - p) \cdot C' \quad (9)$$

Note that there is a special situation in the **hsb** case: if *saturation* = 0 then the color equals a gray color of level *brightness*, independently of the *hue* value. Therefore, to achieve smooth transitions of an arbitrary color to a specific gray (like white or black), we actually use the formulas

$$\text{tint}_{\text{hsb}}(C, p) = p \cdot C + (1 - p) \cdot (\text{hue}, 0, 1) \quad (10)$$

$$\text{shade}_{\text{hsb}}(C, p) = p \cdot C + (1 - p) \cdot (\text{hue}, 0, 0) \quad (11)$$

$$\text{tone}_{\text{hsb}}(C, p) = p \cdot C + (1 - p) \cdot (\text{hue}, 0, \tfrac{1}{2}) \quad (12)$$

where $C = (\text{hue}, \text{saturation}, \text{brightness})$.

From equation (9) and the way how color expressions are being interpreted, as described in section 2.3 on page 12, it is an easy proof by induction to verify that a color expression

$$C_0!P_1!C_1!P_2!\dots!P_n!C_n \quad (13)$$

with $n \in \{0, 1, 2, \dots\}$, colors C_0, C_1, \dots, C_n , and percentages $P_1, \dots, P_n \in [0, 100]$ will result in a parameter vector

$$\begin{aligned} C &= \sum_{\nu=0}^n \left(\prod_{\mu=\nu+1}^n p_{\mu} \right) (1 - p_{\nu}) \cdot C_{\nu} \\ &= p_n \cdots p_1 \cdot C_0 \\ &\quad + p_n \cdots p_2 (1 - p_1) \cdot C_1 \\ &\quad + p_n \cdots p_3 (1 - p_2) \cdot C_2 \\ &\quad + \dots \\ &\quad + p_n (1 - p_{n-1}) \cdot C_{n-1} \\ &\quad + (1 - p_n) \cdot C_n \end{aligned} \quad (14)$$

where $p_0 := 0$ and $p_{\nu} := P_{\nu}/100$ for $\nu = 1, \dots, n$. We note also a split formula:

$$\begin{aligned} C_0!P_1!C_1!\dots!P_{n+k}!C_{n+k} &= p_{n+k} \cdots p_{n+1} \cdot C_0!P_1!C_1!\dots!P_n!C_n \\ &\quad - p_{n+k} \cdots p_{n+1} \cdot C_n \\ &\quad + C_n!P_{n+1}!C_{n+1}!\dots!P_{n+k}!C_{n+k} \end{aligned} \quad (15)$$

6.2 Conversion between integer and real models

We fix a positive integer n and define the sets $\mathcal{I}_n := \{0, 1, \dots, n\}$ and $\mathcal{R} := [0, 1]$. The complement of $\nu \in \mathcal{I}_n$ is $n - \nu$, the complement of $x \in \mathcal{R}$ is $1 - x$.

Table 7: Color constants

<i>model/constant</i>	white	black	gray
rgb	$(1, 1, 1)$	$(0, 0, 0)$	$(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$
cmy	$(0, 0, 0)$	$(1, 1, 1)$	$(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$
cmyk	$(0, 0, 0, 0)$	$(0, 0, 0, 1)$	$(0, 0, 0, \frac{1}{2})$
hsb	$(h, 0, 1)$	$(h, 0, 0)$	$(h, 0, \frac{1}{2})$
Hsb	$(h^\circ, 0, 1)$	$(h^\circ, 0, 0)$	$(h^\circ, 0, \frac{1}{2})$
tHsb	$(h^\circ, 0, 1)$	$(h^\circ, 0, 0)$	$(h^\circ, 0, \frac{1}{2})$
gray	1	0	$\frac{1}{2}$
RGB	(L, L, L)	$(0, 0, 0)$	$(\lfloor \frac{L+1}{2} \rfloor, \lfloor \frac{L+1}{2} \rfloor, \lfloor \frac{L+1}{2} \rfloor)$
HTML	FFFFFF	000000	808080
HSB	$(H, 0, M)$	$(H, 0, 0)$	$(H, 0, \lfloor \frac{M+1}{2} \rfloor)$
Gray	N	0	$\lfloor \frac{N+1}{2} \rfloor$

Table 8: Color conversion pairs

<i>from/to</i>	rgb	cmy	cmyk	hsb	Hsb	tHsb	gray	RGB	HTML	HSB	Gray
rgb	id	*	(cmy)	*	(hsb)	(hsb)	*	*	*	(hsb)	(gray)
cmy	*	id	*	(rgb)	(rgb)	(rgb)	*	(rgb)	(rgb)	(rgb)	(gray)
cmyk	(cmy)	*	id	(cmy)	(cmy)	(cmy)	*	(cmy)	(cmy)	(cmy)	(gray)
hsb	*	(rgb)	(rgb)	id	*	(Hsb)	(rgb)	(rgb)	(rgb)	*	(rgb)
Hsb	(hsb)	(hsb)	(hsb)	*	id	*	(hsb)	(hsb)	(hsb)	(hsb)	(hsb)
tHsb	(Hsb)	(Hsb)	(Hsb)	(Hsb)	*	id	(Hsb)	(Hsb)	(Hsb)	(Hsb)	(Hsb)
gray	*	*	*	*	*	*	id	*	*	*	*
RGB	*	(rgb)	(rgb)	(rgb)	(rgb)	(rgb)	(rgb)	id	(rgb)	(rgb)	(rgb)
HTML	*	(rgb)	(rgb)	(rgb)	(rgb)	(rgb)	(rgb)	(rgb)	id	(rgb)	(rgb)
HSB	(hsb)	(hsb)	(hsb)	*	(hsb)	(hsb)	(hsb)	(hsb)	(hsb)	id	(hsb)
Gray	(gray)	(gray)	(gray)	(gray)	(gray)	(gray)	*	(gray)	(gray)	(gray)	id
wave	(hsb)	(hsb)	(hsb)	*	(hsb)	(hsb)	(hsb)	(hsb)	(hsb)	(hsb)	(hsb)

id = identity function; * = specific conversion function;

(model) = conversion via specified model

6.2.1 Real to integer conversion

The straightforward mapping for this case is

$$\Gamma_n : \mathcal{R} \rightarrow \mathcal{I}_n, \quad x \mapsto \text{round}(n \cdot x, 0) = \lfloor \tfrac{1}{2} + n \cdot x \rfloor \quad (16)$$

where $\text{round}(r, d)$ rounds the real number r to $d \geq 0$ decimal digits. This mapping nearly always preserves complements, as shown in the next lemma.

Lemma 1 (Preservation of complements). *For $x \in \mathcal{R}$,*

$$\Gamma_n(x) + \Gamma_n(1 - x) = n \iff x \notin \mathcal{R}_n^\circ := \left\{ \tfrac{1}{n}(\nu - \tfrac{1}{2}) \mid \nu = 1, 2, \dots, n \right\}. \quad (17)$$

Proof. Let $\nu := \Gamma_n(x)$, then from $-\frac{1}{2} \leq \eta := n \cdot x - \nu < \frac{1}{2}$ we conclude

$$\Gamma_n(1 - x) = \text{round}(n(1 - x), 0) = \text{round}(n - \nu - \eta, 0) = \begin{cases} n - \nu & \text{if } \eta \neq -\frac{1}{2} \\ n - \nu + 1 & \text{if } \eta = -\frac{1}{2} \end{cases}$$

Now, $\eta = -\frac{1}{2} \iff x = \frac{1}{n}(\nu - \frac{1}{2}) \iff x \in \mathcal{I}'_n$. □

Remark: the set \mathcal{R}_n° is obviously identical to the set of points where Γ_n is not continuous.

6.2.2 Integer to real conversion

The straightforward way in this case is the function

$$\Delta_n^* : \mathcal{I}_n \rightarrow \mathcal{R}, \quad \nu \mapsto \frac{\nu}{n}. \quad (18)$$

This is, however, only one out of a variety of solutions: every function $\Delta_n : \mathcal{I}_n \rightarrow \mathcal{R}$ that obeys the condition

$$\nu \in \mathcal{I}_n \Rightarrow \Gamma_n(\Delta_n(\nu)) = \nu \quad (19)$$

which is equivalent to

$$\nu \in \mathcal{I}_n \Rightarrow \nu + \frac{1}{2} > n \cdot \Delta_n(\nu) \geq \nu - \frac{1}{2} \quad (20)$$

does at least guarantee that all integers ν may be reconstructed from $\Delta_n(\nu)$ via multiplication by n and rounding to the nearest integer. Preservation of complements means now

$$\nu \in \mathcal{I}_n \Rightarrow \Delta_n(\nu) + \Delta_n(n - \nu) = 1 \quad (21)$$

which is obviously the case for $\Delta_n = \Delta_n^*$. If we consider, more generally, a transformation

$$\Delta_n(\nu) = \frac{\nu + \alpha}{n + \beta} \quad (22)$$

with $\beta \neq -n$, then the magic inequality (20) is equivalent to

$$\frac{1}{2} > \frac{\alpha n - \beta \nu}{n + \beta} \geq -\frac{1}{2} \quad (23)$$

which is obeyed by the function

$$\Delta'_n : \mathcal{I}_n \rightarrow \mathcal{R}, \nu \mapsto \begin{cases} \frac{\nu}{n+1} & \text{if } \nu \leq \frac{n+1}{2} \\ \frac{\nu+1}{n+1} & \text{if } \nu > \frac{n+1}{2} \end{cases} \quad (24)$$

that has the nice feature $\Delta'_n(\frac{n+1}{2}) = \frac{1}{2}$ for odd n .

Lemma 2 (Preservation of complements). *For odd n and each $\nu \in \mathcal{I}_n$,*

$$\Delta'_n(\nu) + \Delta'_n(n - \nu) = 1 \iff \nu \notin \mathcal{I}_n^\circ := \left\{ \frac{n-1}{2}, \frac{n+1}{2} \right\}. \quad (25)$$

Proof. The assertion is a consequence of the following arguments:

- $\nu < \frac{n-1}{2} \iff n - \nu > \frac{n+1}{2}$ and $\frac{n-1}{2} + \frac{n+1}{2} = n$;
- $\nu < \frac{n-1}{2} \Rightarrow \Delta'_n(\nu) + \Delta'_n(n - \nu) = \frac{\nu}{n+1} + \frac{n-\nu+1}{n+1} = 1$;
- $\nu = \frac{n-1}{2} \Rightarrow \Delta'_n(\nu) + \Delta'_n(n - \nu) = \frac{n-1}{2(n+1)} + \frac{1}{2} = \frac{n}{n+1} \neq 1$. □

For the time being, we choose $\boxed{\Delta_n := \Delta_n^*}$ as default transformation function.

Another variant — which is probably too slow for large-scale on-the-fly calculations — may be used for constructing sets of predefined colors. The basic idea is to minimize the number of decimal digits in the representation while keeping some invariance with respect to the original resolution:

$$\Delta''_n : \mathcal{I}_n \rightarrow \mathcal{R}, \nu \mapsto \text{round}\left(\frac{\nu}{n}, d_n\left(\frac{\nu}{n}\right)\right) \quad (26)$$

where

$$d_n : [0, 1] \rightarrow \mathbb{N}, x \mapsto \min\{d \in \mathbb{N} \mid \Gamma_n(\text{round}(\Delta_n^*(\Gamma_n(x)), d)) = \Gamma_n(x)\} \quad (27)$$

In the most common case $n = 255$ it turns out that we end up with at most 3 decimal digits; preservation of complements is only violated for $\nu \in \{25, 26, 76, 77, 127, 128, 178, 179, 229, 230\}$ where the corresponding set of decimal numbers is $\{0.098, 0.1, 0.298, 0.3, 0.498, 0.5, 0.698, 0.7, 0.898, 0.9\}$.

6.3 Color conversion and complements

We collect here the specific conversion formulas between the supported color models. Table 8 on page 45 gives an overview of how each conversion pair is handled. In general, PostScript (as described in [1]) is used as a basis for most of the calculations, since it supports the color models **rgb**, **cmYk**, **hsb**, and **gray** natively. Furthermore, Alvy Ray Smith's paper [15] is cited in [1] as reference for **hsb**-related formulas.

First, we define a constant which is being used throughout the conversion formulas:

$$E := (1, 1, 1) \quad (28)$$

6.3.1 The **rgb** model

Conversion **rgb to **cmY**** Source: [1], p. 475.

$$(cyan, magenta, yellow) := E - (red, green, blue) \quad (29)$$

Conversion rgb to hsb (1) We set

$$x := \max\{\text{red}, \text{green}, \text{blue}\} \quad (30)$$

$$y := \text{med}\{\text{red}, \text{green}, \text{blue}\} \quad (31)$$

$$z := \min\{\text{red}, \text{green}, \text{blue}\} \quad (32)$$

$$(33)$$

where ‘med’ denotes the median of the values. Then,

$$\text{brightness} := x \quad (34)$$

Case $x = z$:

$$\text{saturation} := 0 \quad (35)$$

$$\text{hue} := 0 \quad (36)$$

Case $x \neq z$:

$$\text{saturation} := \frac{x - z}{x} \quad (37)$$

$$f := \frac{x - y}{x - z} \quad (38)$$

$$\text{hue} := \frac{1}{6} \cdot \begin{cases} 1 - f & \text{if } x = \text{red} \geq \text{green} \geq \text{blue} = z \\ 1 + f & \text{if } x = \text{green} \geq \text{red} \geq \text{blue} = z \\ 3 - f & \text{if } x = \text{green} \geq \text{blue} \geq \text{red} = z \\ 3 + f & \text{if } x = \text{blue} \geq \text{green} \geq \text{red} = z \\ 5 - f & \text{if } x = \text{blue} \geq \text{red} \geq \text{green} = z \\ 5 + f & \text{if } x = \text{red} \geq \text{blue} > \text{green} = z \end{cases} \quad (39)$$

This is based on [15], *RGB to HSV Algorithm (Hexcone Model)*, which reads (slightly reformulated):

$$r := \frac{x - \text{red}}{x - z}, \quad g := \frac{x - \text{green}}{x - z}, \quad b := \frac{x - \text{blue}}{x - z} \quad (40)$$

$$\text{hue} := \frac{1}{6} \cdot \begin{cases} 5 + b & \text{if } \text{red} = x \text{ and } \text{green} = z \\ 1 - g & \text{if } \text{red} = x \text{ and } \text{green} > z \\ 1 + r & \text{if } \text{green} = x \text{ and } \text{blue} = z \\ 3 - b & \text{if } \text{green} = x \text{ and } \text{blue} > z \\ 3 + g & \text{if } \text{blue} = x \text{ and } \text{red} = z \\ 5 - r & \text{if } \text{blue} = x \text{ and } \text{red} > z \end{cases} \quad (41)$$

Note that the singular case $x = z$ is not covered completely in Smith’s original algorithm; we stick here to PostScript’s behaviour in real life.

Because we need to sort three numbers in order to calculate x, y, z , several comparisons are involved in the algorithm. We present now a second method which is more suited for T_EX.

Conversion rgb to hsb (2) Let β be a function that takes a Boolean expression as argument and returns 1 if the expression is true, 0 otherwise; set

$$i := 4 \cdot \beta(\text{red} \geq \text{green}) + 2 \cdot \beta(\text{green} \geq \text{blue}) + \beta(\text{blue} \geq \text{red}), \quad (42)$$

and

$$(\text{hue}, \text{saturation}, \text{brightness}) := \begin{cases} \Phi(\text{blue}, \text{green}, \text{red}, 3, 1) & \text{if } i = 1 \\ \Phi(\text{green}, \text{red}, \text{blue}, 1, 1) & \text{if } i = 2 \\ \Phi(\text{green}, \text{blue}, \text{red}, 3, -1) & \text{if } i = 3 \\ \Phi(\text{red}, \text{blue}, \text{green}, 5, 1) & \text{if } i = 4 \\ \Phi(\text{blue}, \text{red}, \text{green}, 5, -1) & \text{if } i = 5 \\ \Phi(\text{red}, \text{green}, \text{blue}, 1, -1) & \text{if } i = 6 \\ (0, 0, \text{blue}) & \text{if } i = 7 \end{cases} \quad (43)$$

where

$$\Phi(x, y, z, u, v) := \left(\frac{u \cdot (x - z) + v \cdot (x - y)}{6(x - z)}, \frac{x - z}{x}, x \right) \quad (44)$$

The singular case $x = z$, which is equivalent to $\text{red} = \text{green} = \text{blue}$, is covered here by $i = 7$.

It is not difficult to see that this algorithm is a reformulation of the previous method. The following table explains how the transition from equation (39) to equation (43) works:

$6 \cdot \text{hue}$	Condition	$\text{red} \geq \text{green}$	$\text{green} \geq \text{blue}$	$\text{blue} \geq \text{red}$	i
$1 - f$	$\text{red} \geq \text{green} \geq \text{blue}$	1	1	*	6/7
$1 + f$	$\text{green} \geq \text{red} \geq \text{blue}$	*	1	*	2/3/6/7
$3 - f$	$\text{green} \geq \text{blue} \geq \text{red}$	*	1	1	3/7
$3 + f$	$\text{blue} \geq \text{green} \geq \text{red}$	*	*	1	1/3/5/7
$5 - f$	$\text{blue} \geq \text{red} \geq \text{green}$	1	*	1	5/7
$5 + f$	$\text{red} \geq \text{blue} \geq \text{green}$	1	*	*	4/5/6/7

Here, * denotes possible 0 or 1 values. Bold i values mark the main cases where all * values of a row are zero. The slight difference to equation (39) in the last inequality is intentional and does no harm.

Conversion rgb to gray Source: [1], p. 474.

$$\text{gray} := 0.3 \cdot \text{red} + 0.59 \cdot \text{green} + 0.11 \cdot \text{blue} \quad (45)$$

Conversion rgb to RGB As described in section 6.2.1 on page 46.

$$(\text{Red}, \text{Green}, \text{Blue}) := (\Gamma_L(\text{red}), \Gamma_L(\text{green}), \Gamma_L(\text{blue})) \quad (46)$$

Conversion rgb to HTML As described in section 6.2.1 on page 46. Convert to 6-digit hexadecimal afterwards. Certainly, multiplication and summation can be replaced by simple text concatenation of 2-digit hexadecimals.

$$\text{RRGGBB} := (65536 \cdot \Gamma_L(\text{red}) + 256 \cdot \Gamma_L(\text{green}) + \Gamma_L(\text{blue}))_{\text{hex}} \quad (47)$$

Complement of **rgb color** We simply take the complementary vector:

$$(red^*, green^*, blue^*) := E - (red, green, blue) \quad (48)$$

6.3.2 The **cm**y model

Conversion **cmy to **rgb**** This is simply a reversion of the **rgb** \rightarrow **cm**y case, cf. section 6.3.1 on page 47.

$$(red, green, blue) := E - (cyan, magenta, yellow) \quad (49)$$

Conversion **cmy to **cm**yk** This is probably the hardest of our conversion tasks: many sources emphasize that there does not exist any universal conversion algorithm for this case because of device-dependence. The following algorithm is an extended version of the one given in [1], p. 476.

$$k := \min\{cyan, magenta, yellow\} \quad (50)$$

$$cyan := \min\{1, \max\{0, cyan - UCR_c(k)\}\} \quad (51)$$

$$magenta := \min\{1, \max\{0, magenta - UCR_m(k)\}\} \quad (52)$$

$$yellow := \min\{1, \max\{0, yellow - UCR_y(k)\}\} \quad (53)$$

$$black := BG(k) \quad (54)$$

Here, four additional functions are required:

$$UCR_c, UCR_m, UCR_y : [0, 1] \rightarrow [-1, 1] \quad \text{undercolor-removal}$$

$$BG : [0, 1] \rightarrow [0, 1] \quad \text{black-generation}$$

These functions are device-dependent, see the remarks in [1]. Although there are some indications that they should be chosen as nonlinear functions, as long as we have no further knowledge about the target device we define them linearly:

$$UCR_c(k) := \beta_c \cdot k \quad (55)$$

$$UCR_m(k) := \beta_m \cdot k \quad (56)$$

$$UCR_y(k) := \beta_y \cdot k \quad (57)$$

$$BG(k) := \beta_k \cdot k \quad (58)$$

`\adjustUCRBG` where the parameters are given by `\def\adjustUCRBG{\langle\beta_c\rangle,\langle\beta_m\rangle,\langle\beta_y\rangle,\langle\beta_k\rangle}` at any point in a document, defaulting to `\{1,1,1,1\}`.

Conversion **cmy to **gray**** This is derived from the conversion chain **cm**y \rightarrow **rgb** \rightarrow **gray**.

$$gray := 1 - (0.3 \cdot cyan + 0.59 \cdot magenta + 0.11 \cdot yellow) \quad (59)$$

Complement of **cmy color** We simply take the complementary vector:

$$(cyan^*, magenta^*, yellow^*) := E - (cyan, magenta, yellow) \quad (60)$$

6.3.3 The cmyk model

Conversion cmyk to cmy Based on [1], p. 477, in connection with **rgb** \rightarrow **cmy** conversion.

$$cyan := \min\{1, cyan + black\} \quad (61)$$

$$magenta := \min\{1, magenta + black\} \quad (62)$$

$$yellow := \min\{1, yellow + black\} \quad (63)$$

Conversion cmyk to gray Source: [1], p. 475.

$$gray := 1 - \min\{1, 0.3 \cdot cyan + 0.59 \cdot magenta + 0.11 \cdot yellow + black\} \quad (64)$$

Complement of cmyk color The simple vector complement does not yield useful results. Therefore, we first convert $C = (cyan, magenta, yellow, black)$ to the **cmy** model, calculate the complement there, and convert back to **cmyk**.

6.3.4 The hsb model

Conversion hsb to rgb

$$(red, green, blue) := brightness \cdot (E - saturation \cdot F) \quad (65)$$

with

$$i := \lfloor 6 \cdot hue \rfloor, \quad f := 6 \cdot hue - i \quad (66)$$

and

$$F := \begin{cases} (0, 1 - f, 1) & \text{if } i = 0 \\ (f, 0, 1) & \text{if } i = 1 \\ (1, 0, 1 - f) & \text{if } i = 2 \\ (1, f, 0) & \text{if } i = 3 \\ (1 - f, 1, 0) & \text{if } i = 4 \\ (0, 1, f) & \text{if } i = 5 \\ (0, 1, 1) & \text{if } i = 6 \end{cases} \quad (67)$$

This is based on [15], *HSV to RGB Algorithm (Hexcone Model)*, which reads (slightly reformulated):

$$m := 1 - saturation \quad (68)$$

$$n := 1 - f \cdot saturation \quad (69)$$

$$k := 1 - (1 - f) \cdot saturation \quad (70)$$

$$(red, green, blue) := brightness \cdot \begin{cases} (1, k, m) & \text{if } i = 0, 6 \\ (n, 1, m) & \text{if } i = 1 \\ (m, 1, k) & \text{if } i = 2 \\ (m, n, 1) & \text{if } i = 3 \\ (k, m, 1) & \text{if } i = 4 \\ (1, m, n) & \text{if } i = 5 \end{cases} \quad (71)$$

Note that the case $i = 6$ (which results from $hue = 1$) is missing in Smith's algorithm. Because of

$$\lim_{f \rightarrow 1} (0, 1, f) = (0, 1, 1) = \lim_{f \rightarrow 0} (0, 1 - f, 1) \quad (72)$$

it is clear that there is only one way to define F for $i = 6$ in order to get a continuous function, as shown in equation (67). This has been transformed back to equation (71). A similar argument shows that F indeed is a continuous function of hue over the whole range $[0, 1]$.

Conversion hsb to Hsb Only the first component has to be changed.

$$(hue^\circ, saturation, brightness) := (H \cdot hue, saturation, brightness) \quad (73)$$

Conversion hsb to HSB As described in section 6.2.1 on page 46.

$$(Hue, Saturation, Brightness) := (\Gamma_M(hue), \Gamma_M(saturation), \Gamma_M(brightness)) \quad (74)$$

Complement of hsb color We have not found a formula in the literature, therefore we give a short proof afterwards.

Lemma 3. *The hsb-complement can be calculated by the following formulas:*

$$hue^* := \begin{cases} hue + \frac{1}{2} & \text{if } hue < \frac{1}{2} \\ hue - \frac{1}{2} & \text{if } hue \geq \frac{1}{2} \end{cases} \quad (75)$$

$$brightness^* := 1 - brightness \cdot (1 - saturation) \quad (76)$$

$$saturation^* := \begin{cases} 0 & \text{if } brightness^* = 0 \\ \frac{brightness \cdot saturation}{brightness^*} & \text{if } brightness^* \neq 0 \end{cases} \quad (77)$$

Proof. Starting with the original color $C = (h, s, b)$, we define color $C^* = (h^*, s^*, b^*)$ by the given formulas, convert both C and C^* to the **rgb** model and show that

$$C_{\mathbf{rgb}} + C_{\mathbf{rgb}}^* = b \cdot (E - s \cdot F) + b^* \cdot (E - s' \cdot F^*) \stackrel{!}{=} E, \quad (78)$$

which means that $C_{\mathbf{rgb}}$ is the complement of $C_{\mathbf{rgb}}^*$. First we note that the parameters of C^* are in the legal range $[0, 1]$. This is obvious for h^*, b^* . From $b^* = 1 - b \cdot (1 - s) = 1 - b + b \cdot s$ we derive $b \cdot s = b^* - (1 - b) \leq b^*$, therefore $s^* \in [0, 1]$, and

$$b^* = 0 \Leftrightarrow s = 0 \text{ and } b = 1.$$

Thus, equation (78) holds in the case $b^* = 0$. Now we assume $b^* \neq 0$, hence

$$\begin{aligned} C_{\mathbf{rgb}} + C_{\mathbf{rgb}}^* &= b \cdot (E - s \cdot F) + b^* \cdot \left(E - \frac{b \cdot s}{b^*} \cdot F^* \right) \\ &= b \cdot E - b \cdot s \cdot F + b^* \cdot E - b \cdot s \cdot F^* \\ &= E - b \cdot s \cdot (F + F^* - E) \end{aligned}$$

since $b^* = 1 - b + bs$. Therefore, it is sufficient to show that

$$F + F^* = E. \quad (79)$$

From

$$h < \frac{1}{2} \Rightarrow h^* = h + \frac{1}{2} \Rightarrow 6h^* = 6h + 3 \Rightarrow i^* = i + 3 \text{ and } f^* = f$$

it is easy to see from (67) that equation (79) holds for the cases $i = 0, 1, 2$. Similarly,

$$h \geq \frac{1}{2} \Rightarrow h^* = h - \frac{1}{2} \Rightarrow 6h^* = 6h - 3 \Rightarrow i^* = i - 3 \text{ and } f^* = f$$

and again from (67) we derive (79) for the cases $i = 3, 4, 5$. Finally, if $i = 6$ then $f = 0$ and $F + F^* = (0, 1, 1) + (1, 0, 0) = E$. \square

6.3.5 The Hsb model

Conversion Hsb to hsb Only the first component has to be changed.

$$(hue, saturation, brightness) := (hue^\circ / H, saturation, brightness) \quad (80)$$

Conversion Hsb to tHsb Under the settings of (82)–(84) we simply have to exchange the letters x and y in equation (85) to get the inverse transformation:

$$hue^\circ \in [y_{\eta-1}, y_\eta] \Rightarrow hue^\circ := x_{\eta-1} + \frac{x_\eta - x_{\eta-1}}{y_\eta - y_{\eta-1}} \cdot (hue^\circ - y_{\eta-1}) \quad (81)$$

while *saturation* and *brightness* are left unchanged.

6.3.6 The tHsb model

Conversion tHsb to Hsb We assume that `\rangeHsb` = H and `\rangetHsb` expands to

$$x_1, y_1; x_2, y_2; \dots; x_{h-1}, y_{h-1} \quad (82)$$

where

$$x_0 := 0 < x_1 < x_2 < \dots < x_{h-1} < x_h := H \quad (83)$$

$$y_0 := 0 < y_1 < y_2 < \dots < y_{h-1} < y_h := H \quad (84)$$

with an integer $h > 0$. Now the x and y values determine a piecewise linear transformation:

$$hue^\circ \in [x_{\eta-1}, x_\eta] \Rightarrow hue^\circ := y_{\eta-1} + \frac{y_\eta - y_{\eta-1}}{x_\eta - x_{\eta-1}} \cdot (hue^\circ - x_{\eta-1}) \quad (85)$$

while *saturation* and *brightness* are left unchanged.

6.3.7 The gray model

Conversion gray to rgb Source: [1], p. 474.

$$(red, green, blue) := gray \cdot E \quad (86)$$

Conversion gray to cmy This is derived from the conversion chain **gray** → **rgb** → **cmy**.

$$(cyan, magenta, yellow) := (1 - gray) \cdot E \quad (87)$$

Conversion gray to cmyk Source: [1], p. 475.

$$(cyan, magenta, yellow, black) := (0, 0, 0, 1 - gray) \quad (88)$$

Conversion gray to hsb This is derived from the conversion chain **gray** → **rgb** → **hsb**.

$$(hue, saturation, brightness) := (0, 0, gray) \quad (89)$$

Conversion gray to Hsb/tHsb This is derived from the conversion chain **gray** → **hsb** → **Hsb**, followed by **Hsb** → **tHsb** if applicable.

$$(hue^\circ, saturation, brightness) := (0, 0, gray) \quad (90)$$

Conversion gray to Gray As described in section 6.2.1 on page 46.

$$Gray := \Gamma_N(gray) \quad (91)$$

Complement of gray color This is similar to the **rgb** case:

$$gray^* := 1 - gray \quad (92)$$

6.3.8 The RGB model

Conversion RGB to rgb As described in section 6.2.2 on page 46.

$$(red, green, blue) := (\Delta_L(Red), \Delta_L(Green), \Delta_L(Blue)) \quad (93)$$

6.3.9 The HTML model

Conversion HTML to rgb As described in section 6.2.2 on page 46: starting with *RRGGBB* set

$$(red, green, blue) := (\Delta_{255}(RR_{dec}), \Delta_{255}(GG_{dec}), \Delta_{255}(BB_{dec})) \quad (94)$$

6.3.10 The HSB model

Conversion HSB to hsb As described in section 6.2.2 on page 46.

$$(hue, saturation, brightness) := (\Delta_M(Hue), \Delta_M(Saturation), \Delta_M(Brightness)) \quad (95)$$

6.3.11 The Gray model

Conversion Gray to gray As described in section 6.2.2 on page 46.

$$gray := \Delta_N(Gray) \quad (96)$$

6.3.12 The wave model

Conversion wave to rgb Source: based on Dan Bruton's algorithm [4]. Let λ be a visible wavelength, given in nanometers (nm), i.e., $\lambda \in [380, 780]$. We assume further that $\gamma > 0$ is a fixed number ($\gamma = 0.8$ in [4]). First set

$$(r, g, b) := \begin{cases} \left(\frac{440 - \lambda}{440 - 380}, 0, 1 \right) & \text{if } \lambda \in [380, 440[\\ \left(0, \frac{\lambda - 440}{490 - 440}, 1 \right) & \text{if } \lambda \in [440, 490[\\ \left(0, 1, \frac{510 - \lambda}{510 - 490} \right) & \text{if } \lambda \in [490, 510[\\ \left(\frac{\lambda - 510}{580 - 510}, 1, 0 \right) & \text{if } \lambda \in [510, 580[\\ \left(1, \frac{645 - \lambda}{645 - 580}, 0 \right) & \text{if } \lambda \in [580, 645[\\ (1, 0, 0) & \text{if } \lambda \in [645, 780] \end{cases} \quad (97)$$

then, in order to let the intensity fall off near the vision limits,

$$f := \begin{cases} 0.3 + 0.7 \cdot \frac{\lambda - 380}{420 - 380} & \text{if } \lambda \in [380, 420[\\ 1 & \text{if } \lambda \in [420, 700] \\ 0.3 + 0.7 \cdot \frac{780 - \lambda}{780 - 700} & \text{if } \lambda \in]700, 780] \end{cases} \quad (98)$$

and finally

$$(red, green, blue) := ((f \cdot r)^\gamma, (f \cdot g)^\gamma, (f \cdot b)^\gamma) \quad (99)$$

The intermediate colors (r, g, b) at the interval borders of equation (97) are well-known: for $\lambda = 380, 440, 490, 510, 580, 645$ we get *magenta*, *blue*, *cyan*, *green*, *yellow*, *red*, respectively. These turn out to be represented in the **hsb** model by $hue = \frac{5}{6}, \frac{4}{6}, \frac{3}{6}, \frac{2}{6}, \frac{1}{6}, \frac{0}{6}$, whereas $saturation = brightness = 1$ throughout the 6 colors. Furthermore, these **hsb** representations are independent of the actual γ value. Staying within this model framework, we observe that the intensity fall off near the vision limits — as represented by equation (98) — translates into decreasing *brightness* parameters towards the margins. A simple calculation shows that the edges $\lambda = 380, 780$ of the algorithm yield the colors **magenta!0.3 $^\gamma$!black**, **red!0.3 $^\gamma$!black**, respectively. We see no reason why we should not extend these edges in a similar fashion to end-up with true *black* on either side. Now we are prepared to translate everything into another, more natural algorithm.

Conversion wave to hsb Let $\lambda > 0$ be a wavelength, given in nanometers (nm), and let

$$\varrho : \mathbb{R} \rightarrow [0, 1], \quad x \mapsto (\min\{1, \max\{0, x\}\})^\gamma \quad (100)$$

with a fixed correction number $\gamma > 0$. Then

$$hue := \frac{1}{6} \cdot \begin{cases} 4 + \varrho\left(\frac{\lambda - 440}{380 - 440}\right) & \text{if } \lambda < 440 \\ 4 - \varrho\left(\frac{\lambda - 440}{490 - 440}\right) & \text{if } \lambda \in [440, 490[\\ 2 + \varrho\left(\frac{\lambda - 510}{490 - 510}\right) & \text{if } \lambda \in [490, 510[\\ 2 - \varrho\left(\frac{\lambda - 510}{580 - 510}\right) & \text{if } \lambda \in [510, 580[\\ 0 + \varrho\left(\frac{\lambda - 645}{580 - 645}\right) & \text{if } \lambda \in [580, 645[\\ 0 & \text{if } \lambda \geq 645 \end{cases} \quad (101)$$

$$saturation := 1 \quad (102)$$

$$brightness := \begin{cases} \varrho\left(0.3 + 0.7 \cdot \frac{\lambda - 380}{420 - 380}\right) & \text{if } \lambda < 420 \\ 1 & \text{if } \lambda \in [420, 700] \\ \varrho\left(0.3 + 0.7 \cdot \frac{\lambda - 780}{700 - 780}\right) & \text{if } \lambda > 700 \end{cases} \quad (103)$$

For the sake of completeness we note that, independent of γ ,

$$(hue, saturation, brightness) = \begin{cases} \left(\frac{5}{6}, 1, 0\right) & \text{if } \lambda \leq 380 - \frac{3 \cdot (420 - 380)}{7} = 362.857 \dots \\ (0, 1, 0) & \text{if } \lambda \geq 780 + \frac{3 \cdot (780 - 700)}{7} = 814.285 \dots \end{cases}$$

What is the best (or, at least, a good) value for γ ? In the original algorithm [4], $\gamma = 0.8$ is chosen. However, we could not detect significant visible difference between the cases $\gamma = 0.8$ and $\gamma = 1$. Thus, for the time being, xcolor's implementation uses the latter value which implies a pure linear approach. In the `pstricks` examples file `xcolor2.tex`, there is a demonstration of different γ values.

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Appendix

Acknowledgement

This package is based on and contains code copied from [6] (Copyright (C) 1994–1999 David P. Carlisle), which is part of the Standard L^AT_EX ‘Graphics Bundle’. Although many commands and features have been added and most of the original `color` commands have been rewritten or adapted within `xcolor`, the latter package would not exist without `color`. Thus, the author is grateful to David P. Carlisle for having created `color` and its accompanying files.

Trademarks

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Known Issues

- `\rowcolors[\hline]...` does not work with longtable.

History

2005/11/30 v2.08

- New features:
 - more flexibility for `\fcolorbox` arguments, e.g., `\fcolorbox[gray]{0.5}[wave]{580}{test}`;
 - `\boxframe` returns a frame of given dimensions;
 - new implementation of `\f(rame)box` and `\fcolorbox` as an extension of bug report latex/3655 to reduce pixel positioning errors in output devices;
 - `\kernelbox` option for those who prefer the previous `\f(rame)box` approach;
 - experimental `xcdraw` option uses PostScript commands to draw frames and color boxes in case of `dvips`.

- Bugfixes:
 - insufficient expression type detection within `\colorlet`;
 - wrong calculation in the unit interval reduction for negative integers (affecting color series and extended color expressions).

2005/11/12 v2.07

- New features:
 - color model **Hsb** allows to specify *hue* in degrees;
 - color model **tHsb** (*tuned Hsb*) for user-defined *hue* configuration on color wheels;
 - easy generation of color harmonies derived from **Hsb** or **tHsb** color wheels, e.g., `\color{red>wheel,1,12}` yields an ‘analogous’ color to *red* on a 12-spoke wheel;
 - additional 317 predefined color names according to `rgb.txt`, which is part of Unix/X11 distributions;
 - `svgnames` option extended by 4 colors taken from `rgb.txt`;
 - enhanced syntax for immediate conversion, e.g., `\definecolor{foo}{rgb:gray}{0.3}` or `\color[rgb:wave]{478}`;
 - `\@ifundefinedcolor` and `\@ifundefinedmodel` commands;
- Changes:
 - enhanced documentation;
 - several changes to internal macros.
- Bugfixes:
 - wrong calculation of color series components in some cases of negative step parameters.

2005/10/15 v2.06

- New features:
 - color model **wave** for (approximate) visualisation of light wavelengths, still somewhat experimental;

- pseudo-model ‘ps’ for colors defined by literal PostScript code in conjunction with `pstricks` and `dvips`; an illustrative example for a γ -correction approach is given in `xcolor2.tex`;
- `\substitutecolormodel` command for replacement of missing or faulty driver-specific color models;
- improved detection and handling of driver-specific color models;
- `dvipdfmx` and `xetex` options to support these drivers;
- generic driver test file `xcolor4.tex`.
- Changes:
 - `\XC@strip@comma` doesn’t generate a trailing space anymore, which improves also the output of the `testcolors` environment.

2005/09/30 v2.05

- New features:
 - `testcolors` environment helps to test colors in different models, showing both the visual result and the model-specific parameters;
 - `\extractcolorspecs` puts model/color specification into two separate commands, as opposed to `\extractcolorspec`;
 - color names *pink* and *olive* added to the set of predefined colors.
- Bugfixes:
 - `\definecolor{foo}{named}{bar}` did not work in v2.04.

2005/09/23 v2.04

- New features:
 - preparation for usage of additional – driver-provided – color models;
 - `pstricks` users may now specify explicit color parameters within `\psset` and related commands, e.g., `\psset{linecolor=[rgb]{1,0,0}}`; an illustrative example is given in `xcolor2.tex`.

- Changes:
 - color model names sanitized (i.e., turned to catcode 12) throughout the package;
 - `\@namelet` command deprecated because of name clash with `memoir` — please use `\XC@let@cc` instead (more `\XC@let@.` commands are available as well);
 - simplified color conversion code by using the new `\XC@ifxcase` command;
 - some minor changes to internal macros.

2005/06/06 v2.03

- New features:
 - `fixpdfTeX` option loads `pdfcolmk` package in order to improve pdfTeX’s color behaviour during page breaks.
- Changes:
 - some minor changes to internal macros.
- Bugfixes:
 - due to an incorrect `\if` statement within `\XC@info`, `\colorlet` caused trouble whenever its second argument started with two identical letters, e.g., `\colorlet{rab}{oof}`;
 - argument processing of `\XC@getcolor` caused incompatibility with `msc` package;
 - `prologue` option caused incompatibility with `preview` package.

2005/03/24 v2.02

- New features:
 - `\aftergroupedef` command to reproduce `\aftergroupdef`’s behaviour prior to v2.01;
 - xcolor’s homepage www.ukern.de/tex/xcolor.html now provides also a ready-to-run TDS-compliant archive containing all required files.
- Changes:
 - `\rowcolors` and friends are solely enabled by the `table` option;
 - `\@ifxempty` changed back to more robust variant of v2.00.

- Bugfixes:
 - `\psset{linecolor=\ifcase\foo red\or green\or blue\fi}` did not work with `pstricks` (error introduced in v2.01).

2005/03/15 v2.01

- New features:
 - `prologue` option for comprehensive ‘named’ color support in conjunction with `dvips`: on-the-fly generation of PostScript prologue files with all color definitions, ready for `dvips` inclusion and/or post-processing with device-specific parameters (e.g., spot colors);
 - `dvips` prologue file `xcolor.pro` to support additional ‘named’ colors;
 - `\colorlet` may now also be used to create named colors from arbitrary color expressions;
 - enhanced color definition syntax to allow for target-model specific color parameters, e.g., `\definecolor{red}{rgb/cmyk}{1,0,0/0,1,1,0}`, facilitating the usage of tailor-made colors both for displays and printers;
 - ‘deferred definition’ of colors: `\preparecolor` and `\definecolors` enable decoupling of color specification and control sequence generation, especially useful (= memory saving) for large lists of colors, of which only a few names are actually used;
 - `dvipsnames*` and `svgnames*` options to support deferred definition.
- Changes:
 - higher accuracy: most complement calculations are now exact for all 5-digit decimals;
 - `\rangeRGB` and similar variables may now be changed at any point in a document;
 - `\aftergroupdef` now performs only a first-level expansion of its code argument;
 - `\XCfileversion` and similar internal constants removed from `.sty` and `.def` files;

- improved memory management (reduced generation of ‘multiletter control sequences’ by `\@ifundefined` tests);
- several internal macros improved and/or renamed.

• Bugfixes:

- `\XC@getcolor` could cause unwanted spaces when `\psset` was used inside `pspicture` environments (`pstricks`);
- arithmetic overflow could happen when too many decimal digits were used within color parameters, e.g., as a result of `fp` calculations.

2004/07/04 v2.00

- New features:
 - extended functionality for color expressions: mix colors like a painter;
 - support for color blending: specify color mix expressions that are being blended with every displayed color;
 - `\xglobal` command for selective control of globality for color definitions, blends, and masks;
 - multiple step operations (e.g., `\color{foo!!+++}`) and access to individual members (e.g., `\color{foo!![7]}`) in color series;
 - `\providecolor` command to define only non-existent colors;
 - `\definecolorset` and `\providecolorset` commands to facilitate the construction of color sets with common underlying color model;
 - additional 147 predefined color names according to SVG 1.1 specification;
 - `xpdfborder` key for setting the width of hyperlink borders in a more driver-independent way if `dvips` is used.
- Changes:
 - color package now completely integrated within `xcolor`;
 - `override`, `usenames`, `nodvipsnames` options and `\xdefinecolor` command no longer needed;
 - `dvips` and `dvipsnames` options now independent of each other;

- `\tracingcolors`’s behaviour changed to make it more versatile and reduce log file size in standard cases;
- `\rdivide`’s syntax made more flexible (divide by numbers and/or dimensions);
- code restructured, some internal commands renamed;
- documentation rearranged and enhanced.
- Bugfixes:
 - `\definecolor{foo}{named}{bar}` did not work (error introduced in v1.11);
 - more robust behaviour of conditionals within `pstricks` key-values.

2004/05/09 v1.11

- New features:
 - switch `\ifglobalcolors` to control whether color definitions are global or local;
 - option `hyperref` provides color expression support for the border colors of hyperlinks, e.g., `\hypersetup{xurlbordercolor=red!50!yellow}`;
 - internal hooks `\XC@bcolor`, `\XC@mcolor`, and `\XC@ecolor` for additional code that has to be executed immediately before/after the current color is being displayed.
- Changes:
 - `\XC@logcolor` renamed to `\XC@display`, which is now the core color display command;
 - improved interface to `pstricks`.

2004/03/27 v1.10

- New features:
 - support for ‘named’ model;
 - support for *dvips* colors (may now be used within color expressions);
 - internal representation of ‘ordinary’ and ‘named’ colors merged into unified data structure;
 - allow multiple ‘-’ signs at the beginning of color expressions.
- Bugfixes:

- commands like `\color[named]{foo}` caused errors when color masking or target model conversion were active;
- incompatibility with `soul` package: commands `\hl`, `\ul`, etc. could yield unexpected results.

- Documentation:
 - added formula for general color expressions;
 - enhanced text and index;
 - removed dependence of index generation on local configuration file.

2004/02/16 v1.09

- New features:
 - color model **HTML**, a 24-bit hexadecimal **RGB** variant; allows to specify colors like `\color[HTML]{AFFE90}`;
 - color names *orange*, *violet*, *purple*, and *brown* added to the set of predefined colors.
- New xcolor homepage: www.ukern.de/tex/xcolor.html
- Bugfix: `\xdefinecolor` sometimes did not normalise its parameters.
- Changes:
 - slight improvements of the documentation;
 - example file `xcolor1.tex` reorganised and abridged.

2004/02/04 v1.08

- New commands:
 - `\selectcolormodel` to change the target model within a document;
 - `\adjustUCRBG` to fine-tune undercolor-removal and black-generation during conversion to **cmyk**.
- Bugfix: color expressions did not work correctly in connection with active ‘!’ character, e.g., in case of `\usepackage[frenchb]{babel}`.
- Code re-organisation:

- `\XC@xdefinecolor` merged into `\xdefinecolor`, making the first command obsolete;
- several internal commands improved/streamlined.

2004/01/20 v1.07

- New feature: support for color masking and color separation.
- New commands:
 - `\rmultiply` to multiply a dimension register by a real number;
 - `\xcolorcmd` to pass commands that are to be executed at the end of the package.
- Changes:
 - more consistent color handling: extended colors now always take precedence over standard colors;
 - several commands improved by using code from the L^AT_EX kernel.
- Documentation: some minor changes.
- Example files: additional `pstricks` examples (file `xcolor2.tex`).

2003/12/15 v1.06

- New feature: extended color expressions, allowing for cascaded mix operations, e.g., `\color{red!30!green!40!blue}`.
- Documentation: new section on color expressions.
- Bugfix: color series stepping did not work correctly within non-displaying commands like `\extractcolorspec{foo!!+}` (this bug was introduced in v1.05).
- Renamed commands: `\ukfileversion` and similar internal constants renamed to `\XCfileversion` etc.
- Removed commands: `\ifXCpst` and `\ifXCtable` made obsolete by a simple trick.

2003/11/21 v1.05

- Bugfixes:

- package option `hideerrors` should now work as expected;
- usage of ‘.’ in the first color expression in a document caused an error due to incorrect initialisation.

- Code re-organisation: `\extractcolorspec` now uses `\XC@splitcolor`, making `\XC@extract` obsolete.

2003/11/09 v1.04

- New feature: easy access to current color within color expressions.
- New option: `override` to replace `\definecolor` by `\xdefinecolor`.
- New command: `\tracingcolors` for logging color-specific information.

2003/09/21 v1.03

- Change: bypass strange behaviour of some drivers.
- New feature: driver-sharing with `hyperref`.

2003/09/19 v1.02

- Change: `\extractcolorspec` and `\colorlet` now also accept color series as arguments.

2003/09/15 v1.01

- New feature: `\definecolorseries` and friends.
- Documentation: removed some doc-related side-effects.
- Code re-organisation: all calculation-related tools put to one place.
- Bugfixes:
 - `\@rdivide`: added `\relax` to fix problem with negative numerators;
 - `\rowcol@rs`: replaced `\@ifempty` by `\@ifxempty`.

2003/09/09 v1.00

- First published release.

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