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## **Image technology colour management — Black point compensation**

*Élément introductif — Élément central*

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## Foreword

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ISO 18619 was prepared by Technical Committee ISO/TC 130, *Graphic technology*, in cooperation with the International Color Consortium.

## Introduction

Black point compensation (BPC) is a technique used to address colour conversion problems caused by differences between the darkest level of black achievable on one device and the darkest level of black achievable on another. This procedure was first implemented in Adobe Photoshop in the late 1990's. The International Color Consortium (ICC) and ISO Technical Committee 130 (Graphic technology) have created this document to allow black point compensation to be used in a consistent manner across applications.

The purpose of BPC is to adjust a colour transform between source and destination ICC profiles, so that it retains shadow details and utilises available black levels. The procedure depends only on the rendering intent(s) and the source and destination ICC profiles, not on any points in a particular image. Therefore, the colour transform using specific source and destination ICC profiles can be computed once, and then efficiently applied to many images which use the same ICC profile colour transform pair.



# Image technology colour management — Black point compensation

## 1 Scope

This International Standard specifies a procedure, including computation, by which a transform between ICC profiles can be adjusted (compensated) to take into account differences between the dark end of the source colour space and the destination colour space. This is referred to as black point compensation (BPC). The relative colorimetric encoding of ICC profile transforms already provides a mechanism for such adjustment of the light (white) end of the tone scale.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15076-1, *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2010*

ICC.1:2001-04, *File Format for Color Profiles*, Available from [www.color.org](http://www.color.org)

## 3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 15076-1 and the following terms and definitions apply.

### 3.1

#### **Black point compensation (BPC)**

computational procedure by which a transform between ICC profiles can be adjusted (compensated) to take into account differences between the dark end of the source colour space and the dark end of the destination colour space.

### 3.2

#### **DestinationBlackPoint**

coordinate representing a dark neutral reproducible colour in the destination colour gamut

### 3.3

#### **DestinationProfile**

destination ICC profile

### 3.4

#### **L, a, b**

L\*, a\*, or b\* component of the CIELAB colour space.

### 3.5

#### **output-capable CMYK profile**

CMYK profile containing a transform from the ICC PCS encoding to the colour space encoding

**3.6**

**SourceBlackPoint**

coordinate representing a dark neutral colour in the source colour gamut

**3.7**

**SourceProfile**

source ICC profile

**3.8**

**RenderingIntent**

rendering intent of the conversion from a source ICC profile's colour space to a destination ICC profile's colour space.

**3.9**

**transform**

mathematical operations that define the change in representation of a colour between two colour spaces

**3.10**

**gamut**

range of colours that a given system is capable of reproducing

**3.11**

**LabIdentityProfile**

real or virtual ICC profile that contains a bi-directional (identity) transform between CIELAB and PCSLAB

## **4 Requirements**

### **4.1 Constraints**

The black point compensation procedure defined in this International Specification shall take as its inputs a destination ICC profile, a source ICC profile, and a rendering intent (in this document called DestinationProfile, SourceProfile and RenderingIntent respectively).

Applications that apply black point compensation shall support ICC profiles that conform to ISO 15076-1 and ICC profiles that conform to ICC.1:2001-04.

NOTE 1 This requirement ensures that processing applications will properly process all Version 2 and Version 4 ICC profiles.

NOTE 2 ISO 15076-1 provides a description of source and destination ICC profiles.

The rendering intent shall be one of: RelativeColorimetric; Perceptual; or Saturation. The rendering intent used with DestinationProfile shall be the same as the rendering intent used with SourceProfile.

NOTE 3 Other black point compensation procedures might allow different source and destination rendering intents

The versions of SourceProfile and DestinationProfile do not need to match.

SourceProfile and DestinationProfile types shall be Input, Display, Output, or ColorSpace. The types of SourceProfile and DestinationProfile do not need to match.

DestinationProfile shall contain a transform from the ICC PCS encoding to the colour space encoding.

This definition of black point compensation is only defined for the colour spaces Gray, RGB, CMYK and CIELAB.

NOTE 4 Other black point compensation procedures might support other colour spaces.



## 4.2 Computation

### 4.2.1 Outline

Black point compensation shall be performed according to the following procedure:

- 1) The SourceBlackPoint of SourceProfile shall be calculated as specified in section 4.2.3,
- 2) The DestinationBlackPoint of DestinationProfile shall be calculated as specified in sections 4.2.4 and 4.2.5,
- 3) A mapping from SourceBlackPoint to DestinationBlackPoint shall be calculated as specified in section 4.2.6, and
- 4) The mapping shall be applied in a colour conversion as specified in section 4.2.7.

### 4.2.2 Functions used

#### 4.2.2.1 Colour transform with profiles

$T$  shall denote a function to transform a point in the device colour space of Profile1 to a point in the device colour space of Profile2, using a rendering intent, such that

$$y = T(x, Profile1, Profile2, Intent)$$

where

$x$  is a point in the colour space of Profile1,

$y$  is a point in the colour space of Profile2 and

$Intent$  is the rendering intent.

#### 4.2.2.2 Darkest colour of a profile

$D$  shall denote a function to provide the darkest colour coordinate in the device colour space of Profile for a rendering intent, such that

$$dc = D(Profile, Intent)$$

where

$dc$  is the darkest color

$Intent$  is the rendering intent,

$Profile$  is the Profile being evaluated,

$Intent$  is the rendering intent.

$dc$  shall be determined as follows:

A subset of the vertices within the colour space of Profile,  $V$ , shall be defined as follows

If the colour space of Profile is Gray

$V$  shall be the set of  $\{(0) (1)\}$ .

If the colour space of Profile is RGB

$V$  shall be the set of  $\{(0, 0, 0) (1, 1, 1)\}$ .

If the colour space of Profile is CMYK

$V$  shall be the set of  $\{(0, 0, 0, 0) (1, 1, 1, 1)\}$ .

The darkest colour,  $dc$ , shall be the element of  $V$ ,  $v$ , with the lowest value of  $L^*$  resulting from the transform

$T(v, Profile, LabIdentityProfile, Intent)$ .

NOTE 1  $dc$  is intended to be the value of black or darkest colour according to the colour space of Profile.

NOTE 2 Determining the darkest colour in this way works for profiles with both the normal polarity and inverse polarity.

#### 4.2.3 Computing the SourceBlackPoint

The SourceBlackPoint is computed by first defining LocalBlack of SourceProfile and then using this to compute the SourceBlackPoint.

A LocalBlack value for the source colour space shall be defined as follows:

If SourceProfile is an output-capable CMYK ICC profile

LocalBlack shall be set to  $T((0, 0, 0), LabIdentityProfile, SourceProfile, Perceptual)$

If SourceProfile is not an output-capable CMYK ICC profile

If the colour space of SourceProfile is CIELAB,

LocalBlack shall be set to  $(0, 0, 0)$ .

If the colour space of SourceProfile is Gray, RGB, or CMYK,

LocalBlack shall be set to  $D(SourceProfile, RenderingIntent)$ .

The SourceBlackPoint is then calculated as follows

$Li$  shall be set to the  $L$  component of  $T(LocalBlack, SourceProfile, LabIdentityProfile, RenderingIntent)$ .

If  $Li$  is greater than 50,

SourceBlackPoint shall be set to  $(50, 0, 0)$ ,

else

SourceBlackPoint shall be set to  $(Li, 0, 0)$ .

#### 4.2.4 Computing the DestinationBlackPoint for ICC profiles that are not LUT-based

If DestinationProfile is not LUT-based, then its DestinationBlackPoint shall be determined as follows:

A LocalBlack value for the destination colour space shall be determined as follows:

LocalBlack shall be set to  $D(DestinationProfile, RenderingIntent)$ .

NOTE Only Gray and RGB are valid colour spaces for a DestinationProfile that is not LUT-based.

The DestinationBlackPoint is then calculated as follows

*Li* shall be set to the L component of T (LocalBlack, DestinationProfile, LabIdentityProfile, RenderingIntent).

If *Li* is greater than 50,

*DestinationBlackPoint* shall be set to (50, 0, 0),

else

*DestinationBlackPoint* shall be set to (*Li*, 0, 0).

#### 4.2.5 Computing the DestinationBlackPoint for ICC profiles that are LUT-based

##### 4.2.5.1 Overview

If DestinationProfile is LUT-based, then its DestinationBlackPoint shall be determined as follows:

*InitialLab*, *inRamp*, and *outRamp* shall be calculated as specified in section 4.2.5.2.

If *outRamp* is not valid as specified in section 4.2.5.3,

*DestinationBlackPoint* shall be set to (0, 0, 0),

else if *RenderingIntent* is RelativeColorimetric, and the *outRamp* meets the mid range straight test specified in section 4.2.5.4,

*DestinationBlackPoint* shall be set to *InitialLab*,

else

*DestinationBlackPoint* shall be determined as specified in section 4.2.5.5.

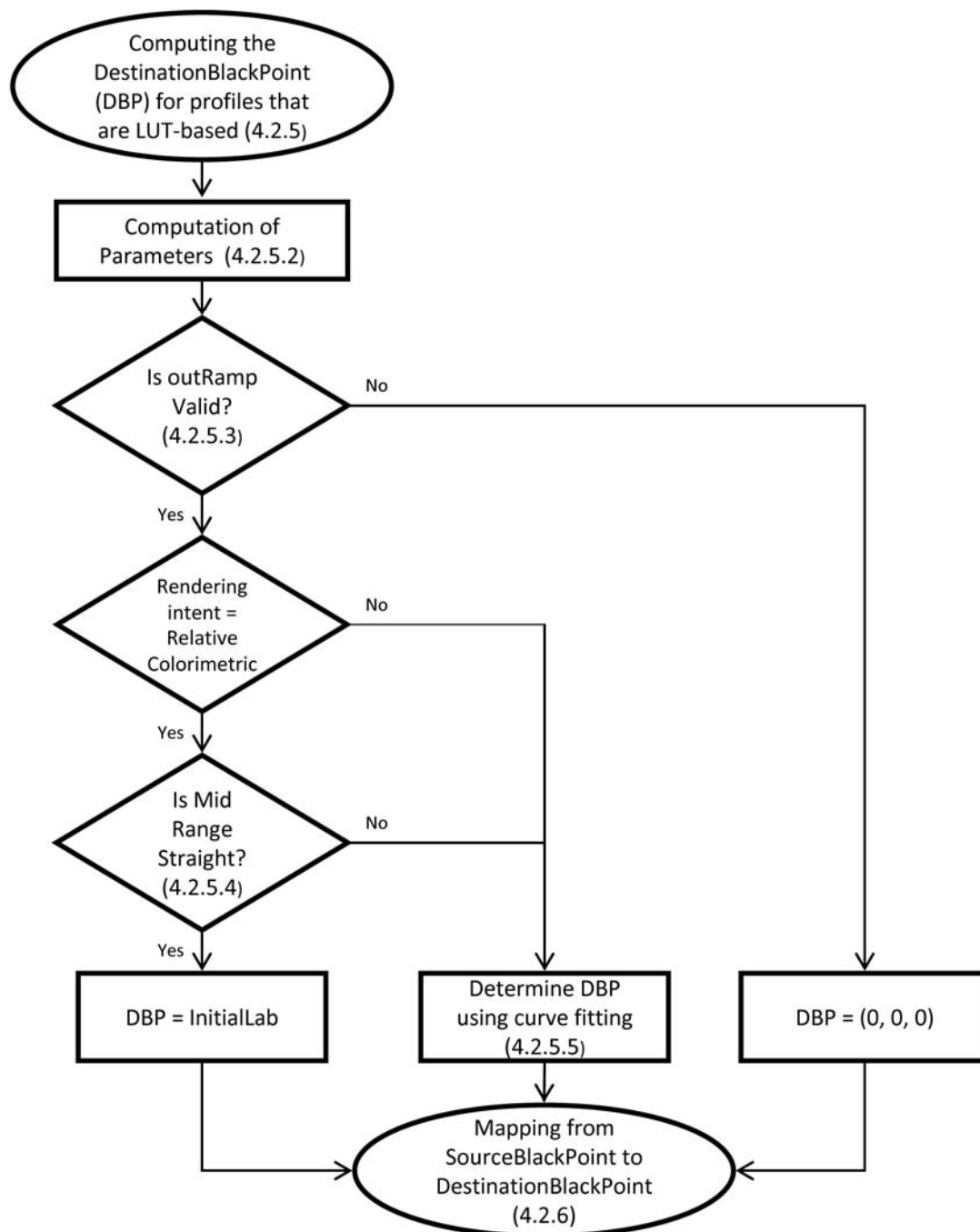


Figure 1 — DestinationBlackPoint computation logic sequence

#### 4.2.5.2 Computation of parameters

##### 4.2.5.2.1 InitialLAB Calculation

If RenderingIntent is not RelativeColorimetric, then *InitialLab* shall be set to (0,0,0), else *InitialLab* shall be calculated as follows:.

If the colour space of DestinationProfile is CMYK

*LocalBlack* shall be set to  $T((0,0,0), LabIdentityProfile, DestinationProfile, Perceptual)$

If the colour space of *DestinationProfile* is *CIELAB*,

*LocalBlack* shall be set to (0,0,0).

If the colour space of *DestinationProfile* is Gray, or RGB,

*LocalBlack* shall be set to *DarkestColour* (*DestinationProfile*, *RenderingIntent*).

*InitialLab* shall be set to  $T(\textit{LocalBlack}, \textit{DestinationProfile}, \textit{LabIdentityProfile}, \textit{RenderingIntent})$ .

If the colour space of *DestinationProfile* is CMYK, then the  $a^*$  and  $b^*$  components of *InitialLab* shall be set to 0.

If the  $L^*$  of *InitialLab* exceeds 50, then the  $L^*$  component of *InitialLab* shall be set to 50.

#### 4.2.5.2.2 Calculation of inRamp

*inRamp* (a list of  $L^*$  values) shall be calculated as follows:

$ka$  shall be  $\min(50, \max(-50, a^* \text{ component of InitialLab}))$ ,

$kb$  shall be  $\min(50, \max(-50, b^* \text{ component of InitialLab}))$ ,

*inRampLab* shall be a list of Lab values interpolated from (0,  $ka$ ,  $kb$ ) to (100, 0, 0) in 256 equal steps,

*inRamp* shall be a list of the  $L$  component values from *inRampLab*.

#### 4.2.5.2.3 Calculation of outRamp

BT is a transform that converts CIELAB colour values from CIELAB space to destination device colour space to CIELAB space, as shown in Figure 2.

$BT(x)$  shall be defined as  $T(y, \textit{DestinationProfile}, \textit{LabIdentityProfile}, \textit{RelativeColorimetric})$  where:

$x$  is a CIELAB colour value,

$y$  is the result of the transform  $T(x, \textit{LabIdentityProfile}, \textit{DestinationProfile}, \textit{RenderingIntent})$ ,

*LabIdentityProfile* is as defined in 3.11,

*DestinationProfile* and *RenderingIntent* are as defined in section 4.1.

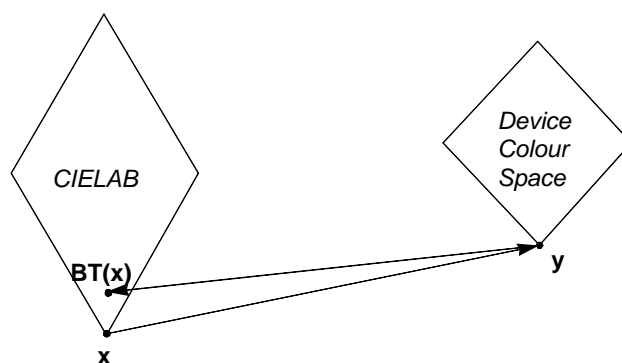


Figure 2 — BT transform

outRampLab shall be set to a list of transformed Lab values found by applying BT to each of the elements of inRampLab

outRamp shall be set to a list of the L\* components of outRampLab.

If outRamp is not monotonically increasing, its values shall be modified to make the list monotonically increasing. This adjustment shall not change the last (lightest) value in the list. This can be accomplished by looping from the second to last element to the first element of outRamp and setting the  $i^{\text{th}}$  element to the minimum of the  $i^{\text{th}}$  element and the element just after the  $i^{\text{th}}$  element. This is shown in the following pseudo code:

for (i=last-1 to first)

$outRamp[i] = \min (outRamp[i], outRamp[i+1])$

where

first indicates the first index of outRamp and

last identifies the last index of outRamp

#### 4.2.5.3 Test for outRamp valid

When outRamp[first] is not less than outRamp[last] then the outRamp is considered invalid and the DestinationBlackPoint shall be set to (0, 0, 0).

#### 4.2.5.4 Test for mid range straight

If RenderingIntent is RelativeColorimetric and the outRamp is valid as determined by section 4.2.5.34.2.6, then the following test shall be applied, otherwise DestinationBlackPoint shall be determined using curve fitting as defined by section 4.2.5.5.

The test for "midrange straight". Is as follows:

Assume that mid range is straight

MinL shall be the value of the first element of outRamp

MaxL shall be the value of the last element of outRamp

For all index values i in inRamp and outRamp

If (not((inRamp[i] <= MinL + 0.2 \* (MaxL - MinL) ) or  
(abs(inRamp[i] - outRamp[i]) < 4 ))) Then

Mid range is not straight.

If the mid range is straight (as determined above) then the DestinationBlackPoint shall be the same as InitialLab. Otherwise, the DestinationBlackPoint shall be determined as specified in section 4.2.5.5.

#### 4.2.5.5 Computation of DestinationBlackPoint using curve fitting

This section defines how to calculate DestinationBlackPoint using curve fitting of inRamp and outRamp.

yRamp shall be set to a list of values:

$yRamp[i] = (outRamp[i] - MinL) / (MaxL - MinL)$  for all valid index values i

where

MinL=outRamp[first] and

MaxL=outRamp[last].

The shadow curve points,  $SP = \{ (inRamp[i], yRamp[i]) \}$ , shall define a set of  $(inRamp[i], yRamp[i])$  points for limited range of index values of  $i$  as follows:

If RenderingIntent is RelativeColorimetric then shadow points are points defined by indices  $i$  where  $0.1 \leq yRamp[i] < 0.5$ ,

Otherwise shadow points are points defined by indices  $i$  where  $(0.03 \leq yRamp[i] < 0.25)$ .

If there are fewer than 3 points in  $SP$  then curve fitting cannot be applied to the data, and the DestinationBlackPoint shall be set to (0, 0, 0).

Otherwise the scalar values,  $a$ ,  $b$ ,  $c$ , shall be determined by using a least-squares error algorithm to fit a quadratic curve of the following form:

$$y = ax^2 + bx + c$$

using the shadow curve points,  $SP$ , as the set of input values to the algorithm.

A value of  $z$  shall be determined to define the DestinationBlackPoint as follows:

If  $(abs(a) < 1.0E-10)$

$z$  shall be set to  $\max(0, \min(50, -c / b))$ ,

else

$d$  shall be set to  $(b^2 - 4ac)$ .

if  $(d \leq 0)$

$z$  shall be set to 0,

else

$z$  shall be set to  $\max(0, \min(50, (-b + \sqrt{d}) / (2a)))$ .

NOTE 1  $z$  has been assigned to the root of the quadratic with the positive gradient. This is either the upper or lower root depending on the sign of  $a$ .

The DestinationBlackPoint shall be set to  $(z, 0, 0)$ .

Figure 3 shows an example of estimating the DestinationBlackPoint using curve fitting. This figure shows an example outRamp, the range of shadow points, the fitted quadratic curve, and the DestinationBlackPoint.

NOTE 2 Curve fitting is actually performed using  $yRamp$  which is a scaled version of outRamp.

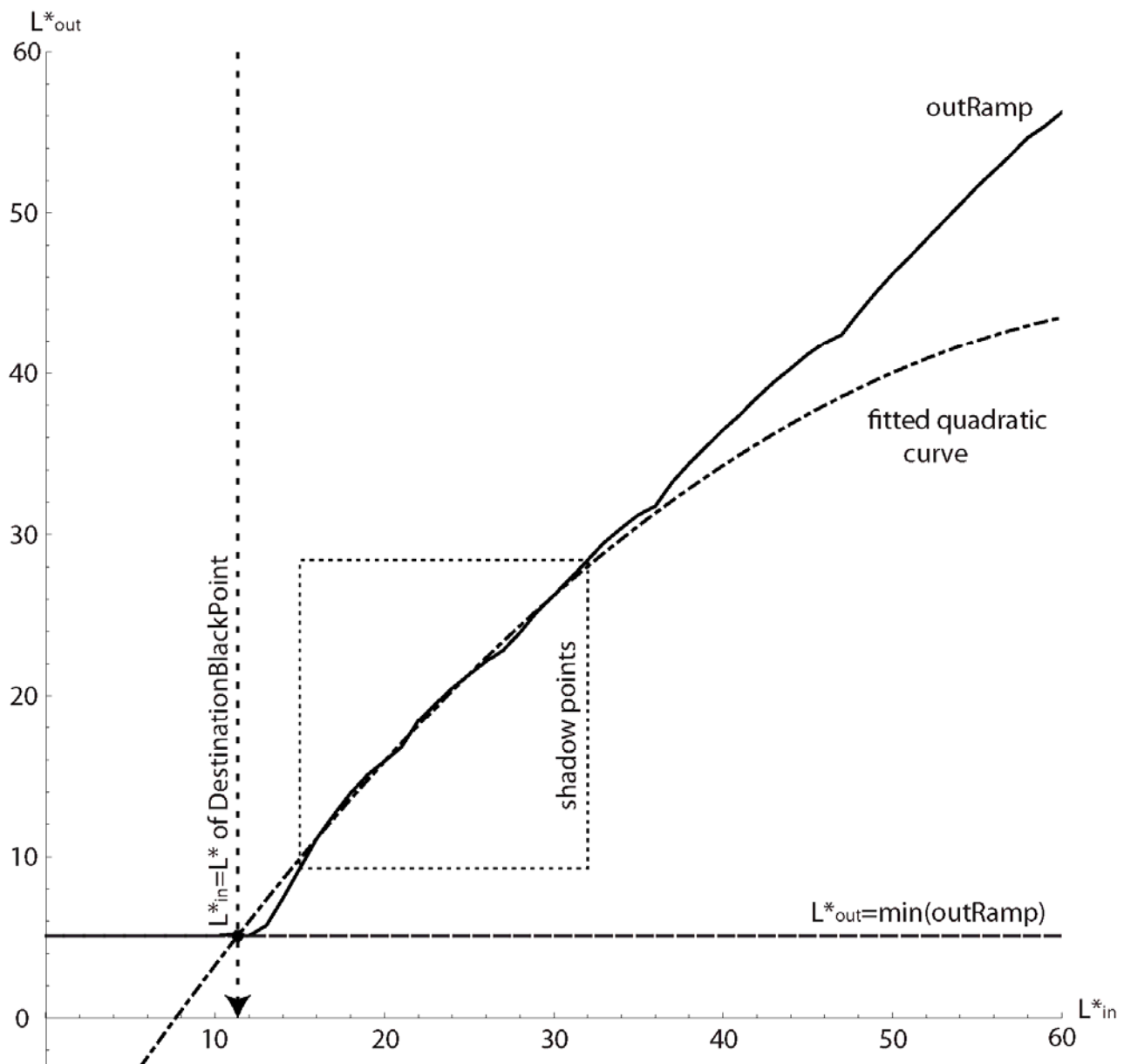


Figure 3 — Example Curve Fitting

#### 4.2.6 Computing the mapping from SourceBlackPoint to DestinationBlackPoint

The mapping from SourceBlackPoint to DestinationBlackPoint shall be accomplished as follows:

Only the  $L$  components of the SourceBlackPoint and DestinationBlackPoint values are used, while the  $a$  and  $b$  components are ignored.

$Y_{DST}$  shall be obtained by converting the  $L$  value of DestinationBlackPoint to a PCSXYZ  $Y$  value using the formula below,

$Y_{SRC}$  shall be obtained by converting the  $L$  value of SourceBlackPoint to a PCSXYZ  $Y$  value using the formula below:

$scaleXYZ$  shall be set to  $(1 - Y_{DST}) / (1 - Y_{SRC})$ ,



*offsetXYZ* shall be set to  $(1 - \text{scaleXYZ}) * W$ .

where

$W = (0.9642, 1.0000, 0.8249)$ , which is the PCSXYZ white point,

and

$$Y = ((L + 16) / 116)^3, \quad \text{for } L > 8.0$$

$$= L \times (((8 + 16) / 116)^3) / 8.0, \quad \text{for } 0 \leq L \leq 8.0.$$

#### 4.2.7 Applying the black point compensation in a colour conversion

Black point compensation is applied at the point in the colour transforms where output results from applying *SourceProfile* are used as the input for applying *DestinationProfile* as follows:

The source device space value shall be converted to PCSXYZ using *SourceProfile* according to *RenderingIntent*, (including conversion from PCSLAB to PCSXYZ when the ICC profile's PCS is PCSLAB).  $XYZ_{SRC}$  shall be the PCSXYZ value resulting from this conversion.

A black point compensated PCSXYZ value ( $XYZ_{DST}$ ) shall be calculated using the equation:

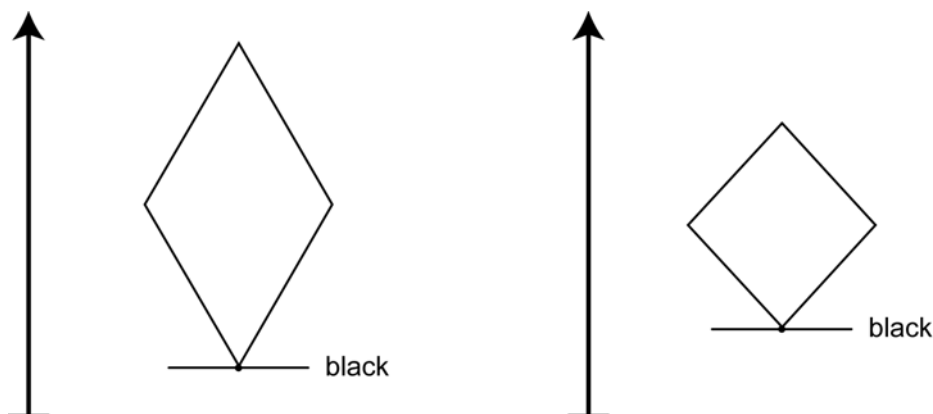
$$XYZ_{DST} = \text{scaleXYZ} * XYZ_{SRC} + \text{offsetXYZ}.$$

The  $XYZ_{DST}$  value shall be converted to device colour space using the *DestinationProfile*, including conversion from PCSXYZ to PCSLAB when the ICC profile's PCS is PCSLAB.

## Annex A (informative)

### Why black point compensation is necessary

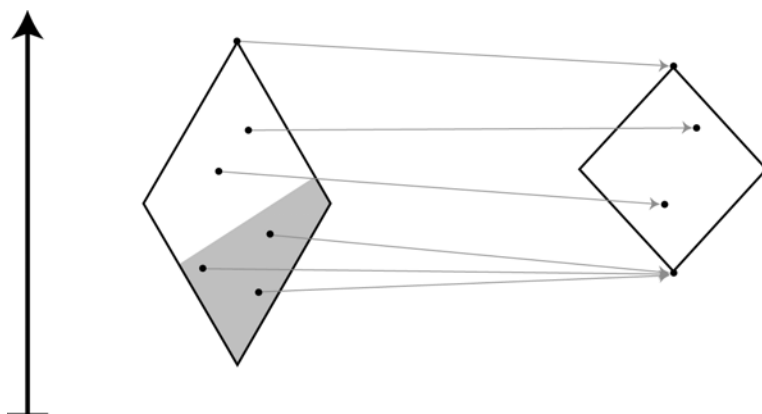
Figure A.1 shows the comparison of a source and destination colour space where no compensation or compression is provided.



**Figure A.1 — Source vs. destination colour spaces**

The colour conversion algorithm consults the ICC profiles of the two devices (the source device and destination device) and the user's rendering intent (or intent) in order to perform the conversion. Although ICC profiles specify how to convert the lightest level of white from the source device to the destination device, the ICC profiles do not specify how black should be converted. The user observes the effect of this missing functionality in ICC profiles when a detailed black or dark space in an image is transformed into an undifferentiated black or dark space in the converted image. The detail in dark regions (called the shadow section) of the image can be lost in standard colour conversion.

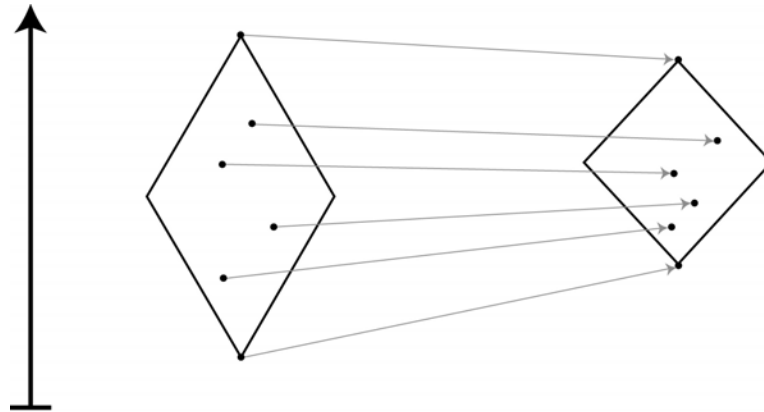
Figure A.2 shows the effect of white point compensation alone as presently defined in ICC profiles.



**Figure 2 — Compression without black point compensation**

BPC can be implemented to address this conversion problem by adjusting for differences between the darkest level of black achievable on one device and the darkest level of black achievable on another. Because BPC is an optional feature that the user can enable or disable when converting an image, the user can always decide whether the conversion of a particular image looks better with or without BPC.

Figure A.3 shows the effect of using both black point and white point compensation.



**Figure A.3 — Compression with black point compensation**

## Bibliography

- [1] ICC White Paper 40, Black Point Compensation, 2010-07-27, available from <http://www.color.org>.
- [2] The Least-Squares Parabola available from [http://www.efunda.com/math/least\\_squares/lstsqr2dcurve.cfm](http://www.efunda.com/math/least_squares/lstsqr2dcurve.cfm).