# INTERNATIONAL STANDARD

# ISO 17957

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# Photography — Digital cameras — Shading measurements

*Photographie — Caméras numériques — Mesurages d'ombrage*



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 42, *Photography*.



 

# Introduction

One common type of image phenomenon seen in digital cameras is a systematic intensity variation across an image known as luminance shading. There are several causes of luminance shading in a digital camera: pixels having non-uniform sensitivity across a sensor array, illumination non-uniformity, lens shading, pixel geometry, and electronic non-uniformity. Characteristics of lens shading include symmetry about the optical sensor, uniformity across each colour plane, and variation as a function of $\cos^n\Theta$. Luminance shading only affects intensity falloff.

Colour variations within the image can be induced by several factors, all of which will cause varying degrees of non-neutrality within an ideal uniform-gray exposure. Some of the primary factors include, (a) a mismatch between the CMOS micro-lens optical acceptance angle and the lens' chief ray angle over the field of view, (b) spatially varying spectral transmittance differences from the infrared rejection filter (usually most significant at the cutoff wavelength), and (c) inherent spectral sensitivity differences across the array. Consistent, systematic variations can be reduced through correction via image processing, but there might remain residual colour variations.

The information that follows defines the recommended approach for creating a test scene to use for the evaluation of luminance shading and colour variations, as well as specifying the conditions for illumination and exposure. The currently proposed analysis approach to quantify the magnitude of colour variations is described. It is important to understand that this specification is related to the degree of colour variations that are apparent in the image, not the specific colour accuracy. Thus, an image that appeared pink but was uniformly pink over the entire image would be equivalent to a perfectly uniform gray field relative to this colour non-uniformity specification.



Some part of this International Standard is based on the work done by the Camera Phone Image Quality group (CPIQ) within the International Imaging Industry Association (I3A), now part of the Institute of Electrical and Electronics Engineers (IEEE), whose contribution is greatly acknowledged.

# Photography — Digital cameras — Shading measurements

## 1 Scope

This International Standard defines a method for measuring shading for digital cameras (including camera phones). The method includes procedures for measuring colour and luminance signal components separately.

## 2 Normative references

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

ISO 7589, *Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer*

ISO 11664-2/CIE, *S 014-2/E: Joint ISO/CIE Standard: Colourimetry — Part 2: CIE Standard Illuminants for Colourimetry*

ISO 11664-4/CIE, *S 014-4/E: Joint ISO/CIE Standard: Colourimetry — Part 4: CIE 1976 L*a*b* Colour Space*

ISO 12231, *Photography — Electronic still picture imaging — Vocabulary*

IEC 61966-2-1:1999+A1:2003: *Multimedia systems and equipment — Colour measurement and management — Part 2-1: Colour management – Default RGB colour space — sRGB*

CIE 15:2004, *Colourimetry*



## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**3.1**
**luminance shading**
**luminance non-uniformity**
gradual variation of the luminance signal components within the image field

**3.2**
**colour shading**
**colour non-uniformity**
gradual variation of the chrominance signal components within the image field

## 4 Test conditions and methods

### 4.1 General

The following measurement conditions should be used as nominal conditions when measuring the shading of a digital camera. If it is not possible or appropriate to achieve these nominal operating conditions, the actual operating conditions shall be listed along with the reported results.

 

## 4.2 Apparatus and hardware

The following hardware is necessary to control and report the test conditions:

— a uniform field target;

— light source(s);

— luminance meter.

The total uniformity required for the target and for the light source(s) is specified below.

## 4.3 Lighting

For lightness non-uniformity and luminance non-uniformity measurement, average outdoor daylight (type D) illuminant shall be used. For chrominance non-uniformity measurement and total colour non-uniformity measurement, three standard illuminants shall be used to represent the characteristics of (a) average outdoor daylight (type D), (b) indoor incandescent lighting (type A), and (c) indoor fluorescent lighting (type F). Other illuminants may be used optionally. The type of illuminant shall be reported in any case.

The recommended daylight illuminant is CIE/D55 (5 503K) with a tolerance of 5 000K to 6 504K. The recommended indoor incandescent illuminant is CIE/A (2 856K) with a tolerance of 2 700K to 3 200K. The recommended fluorescent illuminant is type CIE/F2 (4 230K) with a tolerance of 3 900K to 4 600K.

The light source(s) shall be positioned to provide uniform illumination and produce no glare or reflections from the target.



## 4.4 Test chart



The target shall provide a spectrally neutral, uniform luminance distribution over the entire imaged field of view. Spectral neutrality is achieved if the spectral transmittance or reflectance of the target does not vary by more than 5 % over the range between 420 nm and 750 nm. The construction of the target can be either transmissive or reflective. Total luminance uniformity of the lighting and the test chart is very important for this measurement. The luminance uniformity should be within 2,5 %; (i.e. [|Max-Ave|/Ave < 0,025 and |Min-Ave|/Ave < 0,025]), and shall be within 5 %; (i.e. [|Max-Ave|/Ave < 0,05 and |Min-Ave|/Ave < 0,05]) across the entire imaged area, with an average luminance between 50 cd/m$^2$ and 120 cd/m$^2$. The light flux from the target shall be diffuse and shall not include any specular component.

A target containing patterns may also be used, provided the same results as the uniform chart are obtained by performing a suitable procedure to remove the patterns. When a target containing patterns is used, exposure shall be adjusted to give an average output value of the central measurement block, between 110 and 130 in sRGB encoding values.

## 4.5 Image/camera settings

Exposure shall be adjusted to give an average output value of the central measurement block, between 110 and 130 in sRGB encoding values, when exposure adjustment is available. When average output values of the peripheral measurement blocks are very low (e.g. in the case of very wide-angle lens), the exposure level may be adjusted higher. The average output value of the central measurement block shall be reported in any case.

White balance should be adjusted to render the centre of the image as neutral as possible. Recommended focus distance is equal to or larger than "(35 mm-equivalent) focal length x 10". When the focus may manually be adjusted, focus does not have to be on the test chart. F-number, focal length, focus distance, ISO sensitivity, and exposure time shall be reported. Images should be saved at maximum pixel number using the highest quality (i.e. with least compression) setting.

For the recommended measurement conditions, see Annex A.

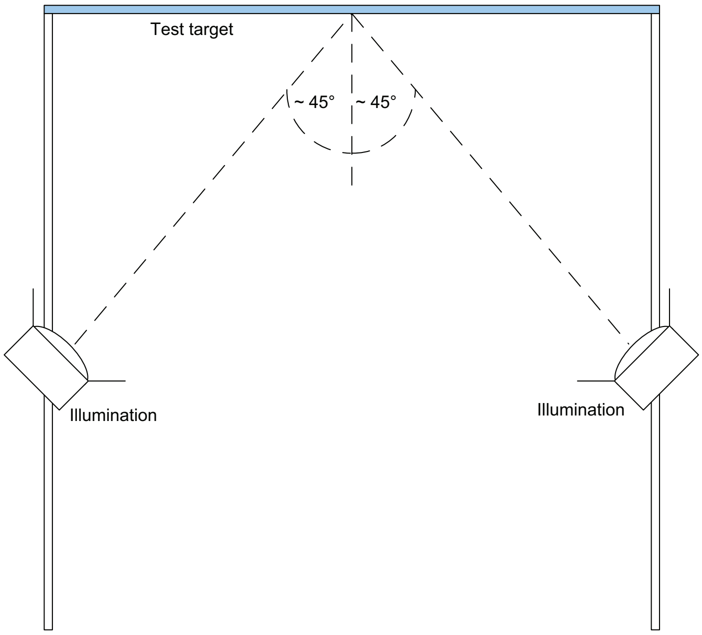


**Figure 1 — Diagram of recommended measurement condition for a reflective target**

## 5 Analytical approach



### 5.1 General

For non-uniformity calculation, the image is divided into (2$N$+1) x (2$N$+1) non-overlapping rectangular blocks ($N \geq 5$), where $N$ should be determined to include sufficient number of pixels for averaging noise and local disturbance for each measurement block. The sRGB values of pixels within one block are averaged. When precipitous variations in the image are visible, it is desirable to increase the "$N$" value so that the precipitous variations will not be averaged out. Mean values of the data should be preserved as floating point or rational numbers as rounding numbers to the nearest code value could result in significant quantization errors.

CIELAB values are calculated from sRGB values as follows:

a) First, the sRGB values of the pixels: $R_j, G_j, B_j$ in the $i$th measurement block will be averaged to $R_{Ave}(i), G_{Ave}(i), B_{Ave}(i)$.

$$R_{Ave}(i) = {}^{1}\!/_{n_i} \cdot \sum_{j=1}^{n_i} R_j \quad G_{Ave}(i) = {}^{1}\!/_{n_i} \cdot \sum_{j=1}^{n_i} G_j \quad B_{Ave}(i) = {}^{1}\!/_{n_i} \cdot \sum_{j=1}^{n_i} B_j \tag{1}$$

where

$R_j, G_j, B_j$ $j$th pixel value in measurement block ($j$=1 to $n_i$);

$n_i$ is the number of pixels in $i$th measurement block.

b) Convert averaged sRGB values: $R_{Ave}(i), G_{Ave}(i), B_{Ave}(i)$ to linear RGB values in the range of 0 to 1: $R_{Lin}(i), G_{Lin}(i), B_{Lin}(i)$

$$R'(i) = R_{Ave}(i)/255 \qquad G'(i) = G_{Ave}(i)/255 \qquad B'(i) = B_{Ave}(i)/255$$

$$\text{if } R'(i), G'(i), B'(i) \le 0{,}040\,45 \qquad (2)$$

$$R_{Lin}(i) = R'(i)/12{,}92 \qquad G_{Lin}(i) = G'(i)/12{,}92 \qquad B_{Lin}(i) = B'(i)/12{,}92$$

Otherwise

$$R_{Lin}(i) = \left[\left(R'(i)+0{,}055\right)/1{,}055\right]^{2,4} \quad G_{Lin}(i) = \left[\left(G'(i)+0{,}055\right)/1{,}055\right]^{2,4} \quad B_{Lin}(i) = \left[\left(B'(i)+0{,}055\right)/1{,}055\right]^{2,4}$$

c) Tristimulus values: $X(i)$, $Y(i)$, $Z(i)$ of the $i$th block are calculated as follows:

$$\begin{bmatrix} X(i) \\ Y(i) \\ Z(i) \end{bmatrix} = \begin{bmatrix} 0{,}412\,4 & 0{,}357\,6 & 0{,}180\,5 \\ 0{,}212\,6 & 0{,}715\,2 & 0{,}072\,2 \\ 0{,}019\,3 & 0{,}119\,2 & 0{,}950\,5 \end{bmatrix} \begin{bmatrix} R_{Lin}(i) \\ G_{Lin}(i) \\ B_{Lin}(i) \end{bmatrix} \qquad (3)$$

d) Convert CIE/XYZ values to CIELAB values: [$L^*(i)$, $a^*(i)$, $b^*(i)$]of the $i$th block as follows (also indicated in IEC 61966-2-1:1999+A1:2003, Annex H). $X_n$, $Y_n$ $Z_n$ are the reference display white point coordinate of illuminant D65 with $X_n$ = 0,9505, $Y_n$ = 1,0000, $Z_n$ = 1,0890.



$$L^*(i) = 116 \cdot f\left(Y(i)/Y_n\right) - 16$$

$$a^*(i) = 500\left[f\left(X(i)/X_n\right) - f\left(Y(i)/Y_n\right)\right]$$

$$b^*(i) = 200\left[f\left(Y(i)/Y_n\right) - f\left(Z(i)/Z_n\right)\right]$$

where

$$\begin{aligned} f\left(X(i)/X_n\right) &= \left(X(i)/X_n\right)^{1/3} && \text{if } X(i)/X_n > 0{,}008\ 856 \\ f\left(X(i)/X_n\right) &= 7{,}787\left(X(i)/X_n\right) + 16/116 && \text{if } X(i)/X_n \le 0{,}008\ 856 \\ f\left(Y(i)/Y_n\right) &= \left(Y(i)/Y_n\right)^{1/3} && \text{if } Y(i)/Y_n > 0{,}008\ 856 \\ f\left(Y(i)/Y_n\right) &= 7{,}787\left(Y(i)/Y_n\right) + 16/116 && \text{if } Y(i)/Y_n \le 0{,}008\ 856 \\ f\left(Z(i)/Z_n\right) &= \left(Z(i)/Z_n\right)^{1/3} && \text{if } Z(i)/Z_n > 0{,}008\ 856 \\ f\left(Z(i)/Z_n\right) &= 7{,}787\left(Z(i)/Z_n\right) + 16/116 && \text{if } Z(i)/Z_n \le 0{,}008\ 856 \end{aligned} \qquad (4)$$

## 5.2 Lightness non-uniformity

The lightness non-uniformity, $D_L$, is defined as:

$$D_L = \max[L^*(i)] - \min[L^*(i)] \qquad (5)$$

## 5.3 Luminance non-uniformity

The luminance non-uniformity, $D_Y$ (%), is defined as:

$$D_Y = \frac{\max[Y(i)] - \min[Y(i)]}{\max[Y(i)]} \times 100 \qquad (6)$$

 

### 5.4 Chrominance non-uniformity

Analysis of the chrominance non-uniformity is performed by first calculating the overall average $\overline{a*}$ and $\overline{b*}$ for the entire image using the block average values: $a^*(i)$ and $b^*(i)$.

$$\overline{a*} = {}^1\!/_m \cdot \sum_{i=1}^{m} a*(i) \qquad \overline{b*} = {}^1\!/_m \cdot \sum_{i=1}^{m} b*(i) \tag{7}$$

where

$m$ is the number of measurement blocks.

The chrominance deviation of the $i$th block is calculated by:

$$D_c(i) = \sqrt{\left[a*(i) - \overline{a*}\right]^2 + \left[b*(i) - \overline{b*}\right]^2} \tag{8}$$

The chrominance non-uniformity, $D_C$, is defined as the maximum deviation from the overall average as:

$$D_c = \max\left[D_c(i)\right] \tag{9}$$

### 5.5 Total colour non-uniformity

Analysis of total colour non-uniformity begins by first calculating the overall maximums and minimums of $L^*(i)$, $a^*(i)$, and $b^*(i)$.



$$L^*_{max} = max\left[L^*(i)\right], \quad L^*_{min} = min\left[L^*(i)\right] \tag{10}$$



$$a^*_{max} = max\left[a^*(i)\right], \quad a^*_{min} = min\left[a^*(i)\right] \tag{11}$$

$$b^*_{max} = max\left[b^*(i)\right], \quad b^*_{min} = min\left[b^*(i)\right] \tag{12}$$

The total colour non-uniformity, $D_{Total}$, is calculated as:

$$D_{Total} = \sqrt{\left(L^*_{max} - L^*_{min}\right)^2 + \left(a^*_{max} - a^*_{min}\right)^2 + \left(b^*_{max} - b^*_{min}\right)^2} \tag{13}$$

## 6 Presentations of results

The following measurement conditions shall be reported for each model. If a condition is unknown, write “unknown”

— Model name/Number: ____________________

— F-Number: ____________________

— Focal length: ____________________

— Focus distance: ____________________

— ISO sensitivity: ____________________

— Exposure time: ____________________

— Average output level of central measurement block: ____________________

 