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Photography — Digital cameras —

Part 2:
Texture analysis using stochastic pattern

Photographie — Caméras numériques —

Partie 2: Analyse de la texture en utilisant un modèle stochastique

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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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared jointly by Technical Committee ISO/TC 42, *Photography*.

A list of all parts in the ISO 19567 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This corrected version of ISO/TS 19567-2:2019 incorporates the following correction:

— The mention of the collaboration with IEC/TC 100, *Audio, video and multimedia systems and equipment*, was removed from the Foreword.

Introduction

In a general context, texture refers to the visual and tactile surface quality derived from the physicality of a material and the roughness or graininess of its surface. For digital still camera images, texture is restricted to the visual surface quality and the characteristic of texture reproduction in the captured image can be interpreted as the reproduction of the low contrast fine details. This document specifies the measurement of how cameras reproduce texture defined as low contrast fine details.

The on going tendency to utilize smaller sensors with higher pixel counts in some cameras leaves a very small amount of light reaching each individual pixel. With the signal getting smaller and the noise level remaining at a certain level, it is necessary to reduce the noise in the image processing after capturing the image. Although the algorithms used for noise reduction have been developed over time, they are still not able to differentiate texture in the actual scene from the unwanted noise introduced by the capturing system. This decreases the image quality and it is therefore helpful to have a method to measure the loss of texture. Texture may also be enhanced to increase the acutance of the image. The texture reproduction is dependent on frequency and contrast because the noise reduction and the acutance enhancement, etc., are nonlinearly dependent on the values of the surrounding pixels.

This document specifies methods to measure texture reproduction using test charts with a stochastic pattern. Annex A talks about the differentiation of this document from ISO/TS 19567-1, which deals with cyclic pattern. The test charts described here are based on randomly arranged circles of various sizes and colour with a limited contrast. This provides a target with known structure and spatial statistics similar to natural images. The measurement results are presented in SFR (Spatial Frequency Response) curves from which a single value representing the overall texture content is derived.

In general if one measured SFR is greater than the other across all measured spatial frequencies, a larger amount of texture is reproduced in the corresponding image. If two SFRs have a crossover point and the larger SFR depends on the frequency range, relative ordering of texture preservation quality is less clear. Comparison of the measurement results can provide important information about the relative texture reproduction of the captured images.

While the measurement method specified in this document is for objective evaluations of texture reproduction for images, their relationship to subjective evaluations of texture reproduction with visual perception is important to give attention, since image quality for camera/photograph users generally accords with subjective evaluation. Annex C explains possible inconsistency between measurement results using the method described in this document and subjective evaluations, due to different condition of noise, with experimental results for images.

Photography — Digital cameras —

Part 2:
Texture analysis using stochastic pattern

1 Scope

This document specifies a protocol to measure the texture reproduction in images captured and processed by digital cameras including cameras in other devices e.g. in camera phones.

This document specifies protocols for the measurement of texture reproduction using test charts with stochastic pattern.

NOTE The measurement method specified in this document is for objective evaluations of texture reproduction, of which the results are sometimes inconsistent with subjective evaluations (See Annex C).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
texture
low contrast fine details, which appear in objects

EXAMPLE Low contrast fine details, which is visible in foliage, fur, sand, textiles, grass, or masonry surfaces.

3.2
texture reproduction
response in the output image of cameras to the texture of the object in the scene

4 Test conditions and methods

4.1 General

The measurement shall be carried out using digital images of the texture test chart captured by a digital still camera.

The following measurement conditions should be used as nominal conditions when measuring the texture reproduction of a digital still 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 Environmental conditions

The measurement shall be carried out in the following environment unless otherwise stated:

— Temperature: 23 °C ± 3 °C.

4.3 Apparatus and hardware

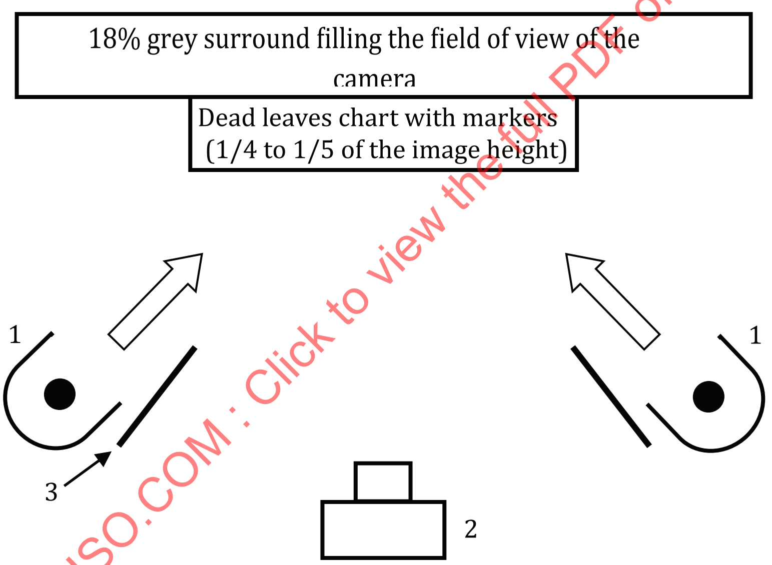
Either a reflective chart or a transmissive chart may be used. The light flux from the target shall be diffuse and shall not include any specular component.

Each test chart shall be specified, together with the lighting conditions such as illuminance, luminance and colour temperature of illumination.

4.4 Arrangement of measuring equipment

4.4.1 Reflective test chart

The arrangement of the measuring equipment for a reflective test chart shall be set up as shown in Figure 1. The camera shall be positioned so that it casts no shadow on the chart. The lamps shall be positioned at an angle which avoids direct specular reflection from the test chart entering the camera.



Key

1 lamp

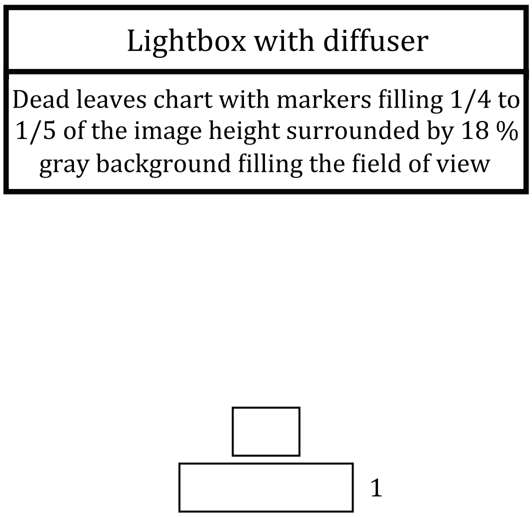
2 digital camera

3 baffles to prevent direct illumination of the camera lens by the lamps

Figure 1 — Arrangement of measuring equipment for reflective test chart

4.4.2 Transmissive test chart

The arrangement of the measuring equipment for a transmissive test chart shall be set up as shown in Figure 2.



Key

1 digital camera

Figure 2 — Arrangement of measuring equipment for transmissive test chart

4.4.3 Lighting

The default colour temperature of the illumination shall be 5 700 K ± 1 000 K. For specific measurements a different colour temperature may be required. In this case the colour temperature shall be reported together with the results. Any illuminance level of the test chart may be applied for the texture reproduction measurement, however the illuminance level in the range from 1 000 lx to 2 000 lx (in the case of transmissive chart, from 57,3 cd/m^2 to 115 cd/m^2 for 18 % grey) is recommended when the measurement has no specified special purpose (e.g. low light performance). Non-uniformity of illumination on the chart shall be less than 10 %. The light source(s) should be positioned to provide uniform illumination and produce no glare or specular reflections from the target. A flickering light source is not recommended as it may cause banding artefacts to occur in the captured image. In the case of using a flickering light source, although it is not recommended, the exposure time shall not be shorter than one period of the flickering to minimize the banding artefacts caused by the light source.

4.4.4 Camera settings

The exposure should be adjusted to give the output value for the background grey near the centre of the measured chart to be the value corresponding to the input value defined below in the camera's output colour space.

(input luminance for grey) = (max input luminance) × (grey reflectance)

For example in the case of an sRGB camera, the output Y for 18 % grey is 118 (8-bit) (see IEC 61966-2-1 and its amendment for details).

The deviation of the exposure should be between +5 % and −10 % of the aforementioned target exposure. For example, when the output colour space of the camera is sRGB 8-bit, the mean output luma Y value for the 18 % grey should be 118 (8-bit) +2, −6.

The exposure shall be in the range of the aforementioned deviation when the measurement results of multiple cameras are compared. (Annex B explains the basic concept for this stipulation.) The exposure may be adjusted by the exposure bias setting of the camera, or by adding a white or black card to the test chart.

White balance should be adjusted to render the centre of the image as neutral as possible.

The focusing shall be in the best practically attainable focus.

For a camera with user selectable compression ratio (e.g. JPEG), the compression ratio should be minimum to minimize the artifacts of compression. The texture reproduction for raw DSC image data should be measured for the output of the software that converts raw DSC image data into the final images. The name and the setting of the software shall be reported with the results of the measurement.

Other settings, such as "sharpness", "noise reduction", shall be in the default mode (factory shipping condition) if those settings are not reported.

4.5 Test Chart

4.5.1 General

"Test chart" shall be "Dead leaves chart with markers" dominating less than a quarter and greater than a fifth of the image height surrounded by an 18 % background. The field of view of the camera shall be covered by the 18 % grey background. The dead leaves chart (also known as spilled coins chart) consists of circles with a random size and colour laid on top of each other. See Figure 3 for a representation of the dead leaves chart.

A vector file of the recommended reference texture chart in EPS format, approximately 8 000 × 8 000 pixels in size is available at:

http://standards.iso.org/iso/ts/19567/-2/ed-1/en

The chart can be printed in various sizes, resolutions and contrast versions. However to reach comparable results the following instructions shall be used when capturing the chart. In order not to measure the resolution of the chart but the resolution of the camera the smallest circles in the chart shall be significantly smaller than the pixel of a camera it is projected on. The largest circle in the image shall cover at least 50 pixels in diameter. The contrast of the chart should be ±9 % around 18 % reflectance.

Additional charts at different mean grey and contrast levels may be used in addition to the above mentioned 18 % ± 9 % grey one.

The size of the Dead leaves with markers should be square and it should cover at least 350 × 350 pixels of the camera under test. To fulfil this and the image height requirement the number of pixels of the camera under test shall have more than 1 400 × 1 400 pixels. In case the camera under test has fewer pixels the height can be larger than a quarter of the field of view which shall be reported together with the results. For cameras with very low distortion it may cover the whole image but generally it should only cover a quarter of the image height to minimize potential distortion for registering the image with the original structure. The pattern can also be smaller and integrated into multi-purpose charts. It is recommended to place it close to the centre of the field of view to avoid lens performance related issues.

The chart shall be printed in a size that the actual printing resolution (not just the smallest printed dot) is at least double the camera sampling rate under the above mentioned chart and image height requirements. The provided sRGB encoded image shall be printed in a colour managed way to ensure the correct tonal and colour range.

4.5.2 Chart generation

The procedure for generating a list of circles for the dead leaves target is fairly straightforward and is in part outlined in Reference [10]. It is based on an occlusion model, with circles generated with a uniform distribution in digital level in the range between 0,09 and 0,27 of the maximum digital output level for each colour channel in a linear (in reflection or transmission) encoded image. A probability distribution should be selected that achieves a power spectral density that closely approximates $1/f^2$, which makes the chart scale-invariant. This can be accomplished with circle radii chosen according to a $1/r^3$ probability distribution, although there shall be an upper and lower bound for the radii (r_{min} and r_{max} respectively) to avoid full coverage by the smallest or largest circles, as discussed in Reference [10].

Typically, r_{min} is chosen such that the image size of the smallest circles will be much less than the image pixels when the target is projected onto the camera sensor array; r_{max} is selected to be much larger than r_{min}, but generally not larger than the width of the dead leaves image in the chart, W. The centre of each circle is randomly placed on a square canvas of width $W + 2r_{max}$; during the actual rendering (printing) phase it is assumed that only the centre $W \times W$ area is reproduced. Circles whose entire area falls outside of the inner $W \times W$ image are obviously excluded from the final list.

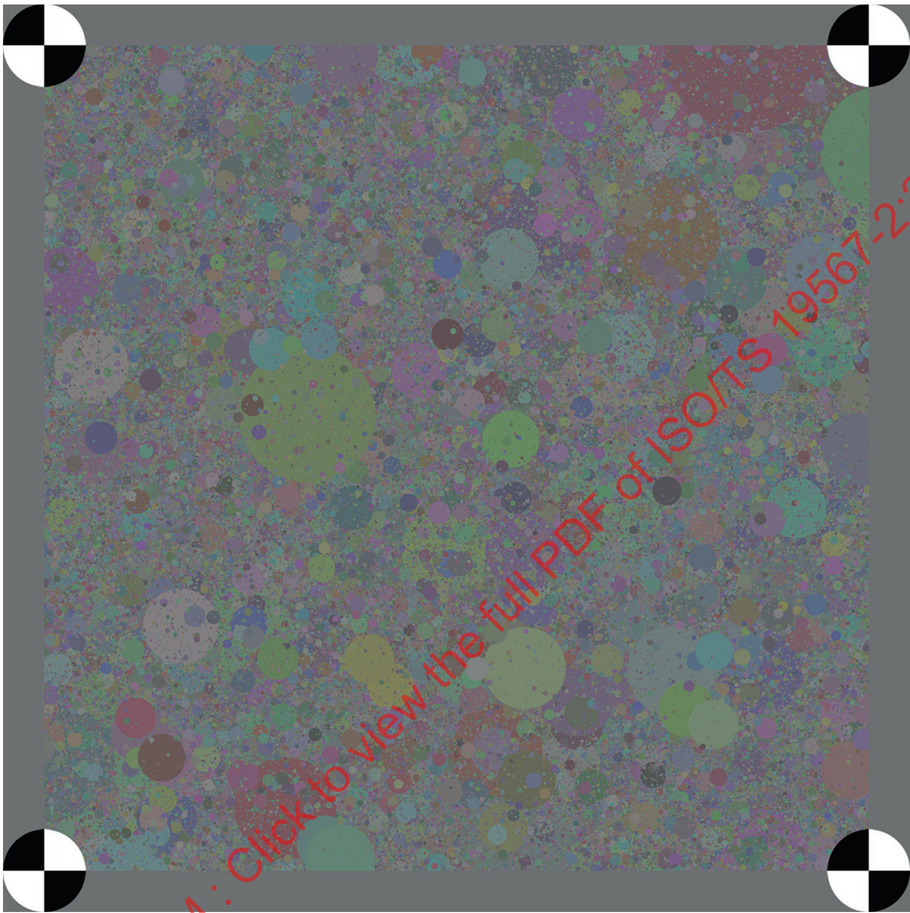


Figure 3 — Dead leaves chart with markers (central part of the test chart)

5 Analytical approach

5.1 General

Texture reproduction is measured from an image of the dead leaves target as described in this technical specification. The frequency characteristics of the texture reproduction are measured for various frequencies using a full reference method with the known spatial information of the pattern to obtain the complete transfer function.

To be able to neglect the local influence of geometric distortion on the target, the test pattern shall cover less than one quarter and more than one fifth of the image height and shall be located as close to the image centre as possible.

The dependency of the evaluation on the distortion has been tested for distortion levels of the Dead Leaves chart up to 3 % local geometric distortion according to ISO 17850. Any significant distortion above 3 % caused deviations in the measured spatial frequency response curve. Therefore this measurement method is only valid for distortion levels of the Dead Leaves chart up to 3 %. Distortion levels above that would need to be corrected prior to performing this analysis but be aware that distortion correction may affect the SFR measurement. In the case that distortion correction is performed for the measurement; the notification that distortion correction is performed for the measurement shall be reported with the measurement result.

NOTE Some cameras perform internal distortion correction without notification to the user. In these cases the correction is treated as part of the camera characteristic.

5.2 Measurement method

The measurement is performed as follows.

— Step 1: The image data shall be linearized using either the tone curve information of the output colour space or a dedicated OECF measurement as stated in ISO 14524 and be reduced to a single luminance channel Y. Also the reference data shall be reduced to a single luminance channel Y. The factors shown in Formula (1) are consistent with the sRGB standard IEC 61966-2-1. They are slightly different from other ISO TC 42 standards but more recent and more accurate.

$$Y = 0{,}212\,6R + 0{,}715\,2G + 0{,}072\,2B \tag{1}$$

— Step 2: The corners of the dead leaves target shall be located with at least half a pixel accuracy using the four markers placed in the corners of the target.

— Step 3: The vector version of the reference data shall be transformed projectively as described in Reference [11] to fit the image data using the corners of the target as located in the image data in step 2 to calculate the transformation matrix $[M]_{\text{proj}}$ [see Formula (3)] by solving the matrix shown in Formula (2)[11] $(u_{1-4}|v_{1-4})$ are the coordinates of the target vertices in the image and $(x_{1-4}|y_{1-4})$ are the corresponding coordinates of the reference vector data vertices. The projectively transformed vector data of the reference is then converted into an uncompressed or lossless compressed reference image with the same pixel count as the test image using a raster image processor.

In case of using the Qt open source platform the vector-raster conversion is performed the following way: The class QPainter is needed for drawing the circles, choosing a brush (Qt::solidPattern) and a pen (Qt::SolidLine) with a pen width of 0,30 pixels. The resulting reference image can be saved by using the class QPixmap.

$$\begin{pmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \end{pmatrix} = \begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -x_1u_1 & -y_1u_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -x_1v_1 & -y_1v_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -x_2u_2 & -y_2u_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -x_2v_2 & -y_2v_2 \\ x_3 & y_3 & 1 & 0 & 0 & 0 & -x_3u_3 & -y_3u_3 \\ 0 & 0 & 0 & x_3 & y_3 & 1 & -x_3v_3 & -y_3v_3 \\ x_4 & y_4 & 1 & 0 & 0 & 0 & -x_4u_4 & -y_4u_4 \\ 0 & 0 & 0 & x_4 & y_4 & 1 & -x_4v_4 & -y_4v_4 \end{bmatrix} \times \begin{pmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \end{pmatrix} \tag{2}$$

$$[M]_{\text{proj}} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix} \tag{3}$$

— Step 4: For further processing, image and reference shall be cropped square so that the image edge length is 2^m pixels, where m is an integer, and the reference shall be cropped to the matching image area and not contain any parts of the marker. The cropped square image area with $i_{\max} \times i_{\max}$ pixels shall cover the largest area possible of the dead leaves chart excluding markers. In addition, the respective mean value $\overline{Y}$ is subtracted from both, image and reference [see Formula (4)]. To avoid leakage, a window function [Formula (5)] with the parameter r = 0,25 is applied to the crops, strongly decreasing from the edge to prevent losing too much image information.

$$Y_{\text{im}} = Y_{\text{im}} - \overline{Y_{\text{im}}}$$
$$Y_{\text{ref}} = Y_{\text{ref}} - \overline{Y_{\text{ref}}} \quad (4)$$

$$w(x) = \begin{cases} \frac{1}{2}\left\{1+\cos\left(\frac{2\pi}{r}\left[x-r/2\right]\right)\right\} & 0 \le x < \frac{r}{2} \\ 1 & \frac{r}{2} \le x < 1-\frac{r}{2} \\ \frac{1}{2}\left\{1+\cos\left(\frac{2\pi}{r}\left[x+1-r/2\right]\right)\right\} & 1-\frac{r}{2} \le x < 1 \end{cases} \quad (5)$$

with x being the horizontal normalized coordinate of the pixel around which the window is created with the pixel count ranging from 0 to i_{max} -1 normalized by i_{max}. The same has to be applied to y which is the normalized vertical coordinate to get to a two dimensional window.

— Step 5: The signals of image $Y(f_h, f_v)$ and reference target $X(f_h, f_v)$ shall be calculated using the Fourier transformation on the mean-corrected and windowed 2-D data. Based on $Y(f_h, f_v)$ and $X(f_h, f_v)$, the cross power density $\phi_{YX\_org}(f_h, f_v)$ of target and image and the auto power density $\phi_{XX\_org}(f_h, f_v)$ of the target are calculated as described in Formula (6):

$$\phi_{XX\_org}(f_h, f_v) = X(f_h, f_v) \cdot X^*(f_h, f_v)$$
$$\phi_{YX\_org}(f_h, f_v) = Y(f_h, f_v) \cdot X^*(f_h, f_v) \quad (6)$$

— Step 6: A smoothing step on the cross power density $\phi_{YX\_org}(f_h, f_v)$ and the auto power density $\phi_{XX\_org}(f_h, f_v)$ shall be performed by transforming them back into the spatial domain, then applying a narrow window [see Formula (7)]. The results are then transformed into the frequency domain again.

$$w(n) = a_0 - a_1\cos\left(\frac{2\pi n}{N}\right) + a_2\cos\left(\frac{4\pi n}{N}\right) + a_3\cos\left(\frac{6\pi n}{N}\right) \qquad 0 \le n \le N-1$$

with the coefficients:

$$a_0 = 0{,}358\ 75$$
$$a_1 = 0{,}488\ 29 \quad (7)$$
$$a_2 = 0{,}141\ 28$$
$$a_3 = 0{,}011\ 68$$

with n being the pixel coordinate around which the window is created and N being the width/height of the window.

— Step 7: To obtain the transfer function $H(f_h, f_v)$, the ratio of the cross power density $\phi_{YX}(f_h, f_v)$ of target and image and the auto power density $\phi_{XX}(f_h, f_v)$ of the target shall be determined see Formula (8):

$$H(f_h, f_v) = \frac{\phi_{YX}(f_h, f_v)}{\phi_{XX}(f_h, f_v)} \quad (8)$$

— Step 8: Finally, the average (ringmean) of the real part of the 2D transfer function $H(f_h, f_v)$ shall be determined for each frequency resulting in the 1D representation $SFR(f)$ of the modulation.

The arithmetic mean of the 2D-DFT (discrete fourier transform) over all possible directions is computed, resulting in a one dimensional profile. This procedure called "ringmean" is calculated in these steps:

1) Calculate a matrix "2D-Freq". This matrix is the same size as the 2D-DFT, each entry corresponds to the spatial frequency at that position, depending on the distance to the DC component [frequency = (0,0)].

2) Define evenly spaced bins based on the selected pixel count in a range of frequency = 0 to frequency = 0,5 cycles per pixel.

3) Every entry in the 2D-DFT is sorted according to the 2-norm of the corresponding frequency vector (f_x,f_y) and its real component is placed into the matching bin.

4) The arithmetic mean of each bin is calculated.

The resulting $SFR(f)$ is normalized by the value at the frequency f_{norm}:

$$f_{norm} = 3\frac{1}{N} \tag{9}$$

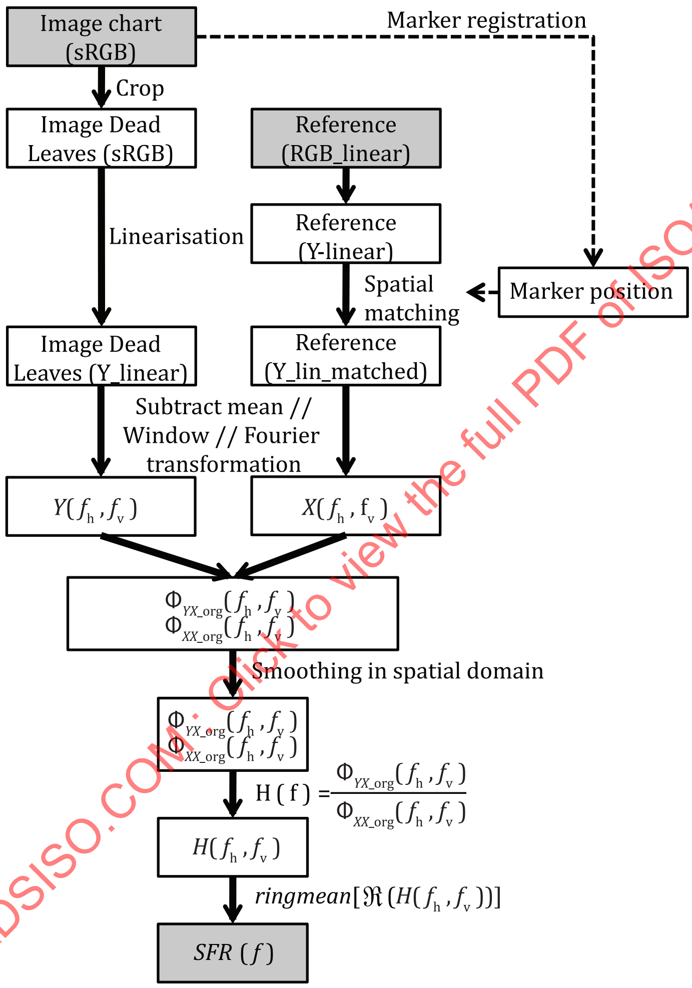


Figure 4 — Flow chart of the SFR_{DL} algorithm

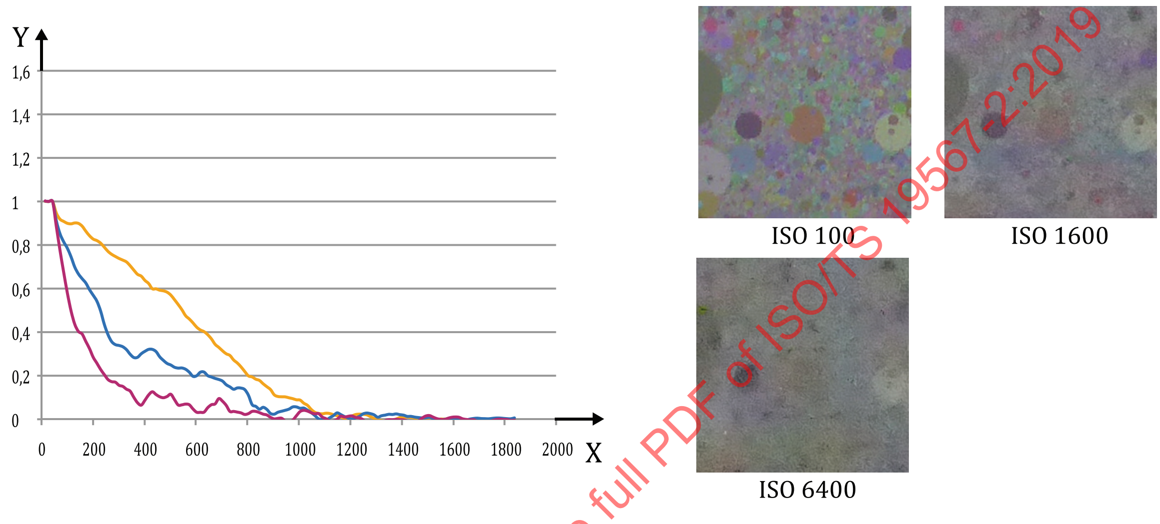
6 Presentation of results

6.1 SFR curve

The measurement results shall be presented as a graph of the texture modulation over the frequency, see Figure 5. The performance of the digital cameras can be compared using the SFR. Given SFR measurements of two different image data, if one measured SFR is greater than the other across all measured spatial frequencies, then a larger amount of texture is reproduced in the corresponding image. On the other hand, if the greater SFR depends on the frequency, then the superior texture reproduction in a subjective evaluation is dependent on the frequency structure of the image. Comparison of the measurement results can provide important information about the relative texture reproduction of the captured images.

The SFR curve for presentation shall be the average of a minimum of four replicate SFR measurements of a dead leaves chart. In high noise conditions, local fluctuations of SFRs tend to occur. In this case, sufficient number of replicate SFR measurements should be averaged. Averaging SFR curves is done by averaging response values of replicate measurements for each frequency.

The linearization method shall be reported together with the result. In the case of comparing the texture loss of cameras, the same linearization method shall be used.



Key

X frequency (lp/ph)

Y *SFR*

— *iso*100

— *iso*600

— *iso*6400

NOTE These images were linearized using the inverse of the tonal output curve for the colour encoding.

Figure 5 — Example of the result of dead leaves measurement with sensitivity settings as specified in ISO 12232 (Frequency values in line pairs per picture height)

6.2 Single numerical values

6.2.1 General

No single value can fully describe a measured SFR curve. In order to characterize the texture reproduction of a camera it is necessary to look at and interpret the full SFR curve. On the other hand, some single numerical values described below are able to be derived from the SFR curve. Relations in certain extent between these values and visual evaluations might be expected by theoretical consideration, however it is important to pay attention that the relations are not verified.

6.2.2 SFR10

SFR10 is the spatial frequency that leads to an SFR of 10 %. The SFR10 value is correlated with the maximum texture frequency that is reproduced.

6.2.3 SFR50

SFR50 is the spatial frequency that leads to an SFR of 50 %. While the SFR10 value relates to the maximum texture frequency, it does not reflect the SFR in lower spatial frequencies that correlate with the perception of sharpness. Sharpening can have an impact on the SFR50 value.

NOTE Be aware that the SFR50 value is only an indicator for the strength of the sharpening. To reflect the sharpness in general it is necessary to look at more than just one modulation level.

6.2.4 Texture acutance

6.2.4.1 General

Texture acutance is basically calculated as the integral under the SFR curve from 0 to Nyquist frequency divided by the integral for the ideal SFR curve which is 1 from 0 to Nyquist frequency [See Formula (10) and (11)]. This simple texture acutance is usable as an alternative for MTF50. It reflects more than one modulation/frequency pair. For a specific viewing condition the SFRs may be multiplied with the contrast sensitivity function (CSF) of the human eye [See Formula (12)]. Be aware that the texture acutance is also impacted by sharpening.

$$A = \frac{\int_0^{\text{Nyquist}} SFR(f)\,\mathrm{d}f}{\int_0^{\text{Nyquist}} 1\,\mathrm{d}f} \tag{10}$$

$$A = \frac{\int_0^{\text{Nyquist}} SFR(f) \cdot csf_{\text{lum}}(f)\,\mathrm{d}f}{\int_0^{\text{Nyquist}} csf_{\text{lum}}(f)\,\mathrm{d}f} \tag{11}$$

When the texture acutance is used the related viewing condition used to apply the CSF shall be reported.

6.2.4.2 Applying the contrast sensitivity function

In the frequency domain, each response is weighted by a set of corresponding spatial responses of the human visual system. There are many aspects that affect the contrast sensitivity of the human eye. It is necessary, therefore, to select a set that is representative of typical viewing conditions. The CSF used for the luminance channel is based on the work of Movshon.

The function used to model the CSF for the luminance channel, A, is given by:

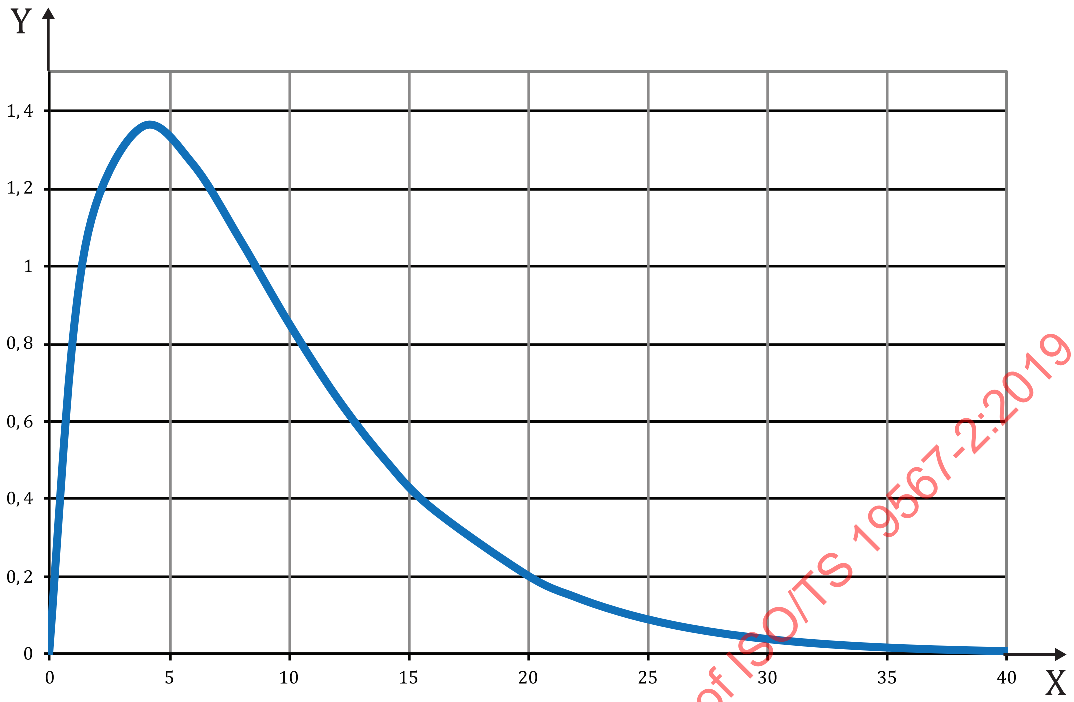
$$csf_{\text{lum}}(f) = a \cdot f^{c} \cdot e^{-bf} \tag{12}$$

where the variables used are given in Table 1.

Table 1 — Variables used for the luminance CSF function

Luminance channel (*A*) variables	
a	1
b	0,2
c	0,8

The frequency, f, is specified in units of cycles per degree of visual angle.



Key

X frequency (cycles/degree)

Y contrast sensitivity

Figure 6 — The contrast sensitivity function of the human eye used in this standard

Before applying the CSF models to the frequency data computed in Step 8 of 5.2, the data need to be first converted from units of cycles per pixel to the units of cycles per degree of visual angle. The maximum frequency that can be represented in an image, according to Nyquist, is 0,5 cycles per pixel. In order to convert the frequency in cycles per pixel into the cycles per degree that is used for the contrast sensitivity of the human eye we need to know the size of each pixel (pixel pitch) in the final picture viewed by the observer and the viewing distance. The viewing angle, α, subtended by one pixel pitch is given by Formula (13)

$$\tan(\alpha) = \frac{P}{D} \Rightarrow \alpha = \frac{180^\circ}{\pi} \arctan\left(\frac{P}{D}\right) \tag{13}$$

where

P is the pixel pitch;

D is the viewing distance.

The frequency in cycles per degree is given as:

$$f_{\left[\frac{\text{cycles}}{\text{degree}}\right]} = f_{\left[\frac{\text{cycles}}{\text{pixel}}\right]} \cdot \frac{1}{\alpha} \tag{14}$$

NOTE The assumption in this calculation is that the image is displayed on a “theoretical display” with unlimited resolution but not resampled. For real viewing the physical display resolution as well as the SFR of the display has an impact and may require the image to be resampled which also affects the acutance.

Annex A
(informative)

Differentiation of cyclic pattern and stochastic pattern

The reason to create the series of ISO/TS 19567 is that the noise reduction, which is applied in cameras when images are captured at lower light levels, affects the reproduction of fine detail. For systems without non linear noise reduction applied to the images the resolution measurement described in the resolution standard ISO 12233 is sufficient. A relatively high contrast oriented structure like a slanted edge or a sinusoidal Siemens star can be used to describe the detail reproduction of these systems.

In case non linear noise reduction is used the related algorithm tries to differentiate the noise introduced into the picture by the camera sensor and electronics from structures in the original scene. It then tries to delete only the noise without affecting the scene structures. The lower the contrast of the structure in the original scene and the less oriented it is the more difficult it is for the algorithms to differentiate it from noise.

Since it is relatively easy to produce and analyse ISO/TS 19567-1 which describes sinusoidal cyclic patterns that are reduced in contrast. This has been the first reliable approach on how to measure the reproduction of low contrast structures and that way to characterize the reproduction of texture.

Looking at the latest generation of noise reduction algorithms it becomes clear that these algorithms are capable of identifying oriented structures even at low contrast, including the low contrast cyclic patterns described in ISO/TS 19567-1. They apply a different noise reduction to these structures than to structures that have no identifiable orientation and therefore are closer to the characteristics of noise. This was the reason to create this document focusing on stochastic pattern.

Even though this document may in the future be sufficient to describe the texture loss in general it may in some cases be interesting to differentiate the behaviour of systems on oriented and stochastic structures. Therefore it makes sense to keep and use both approaches for the full picture on noise reduction and texture reproduction of a camera system.

Figure A.1 shows an overview of structure of texture. Structure with high autocorrelation in one direction is categorized as oriented structure, which includes multiburst and siemens star used in the charts specified in ISO/TS 19567-1. Structure with low autocorrelation is categorized as less oriented or stochastic structure, which includes dead leaves used in the chart specified in this document.

NOTE The terms in Figure A.1 are different from the terms in ISO/TS 19567-1:2016, Figure A.1, for the same categorization purpose. “Oriented structure” in this document corresponds to “Structured texture” in ISO/TS 19567-1, and “Less-oriented/stochastic structure” in this document corresponds to “Non-structured/random texture” in ISO/TS 19567-1.

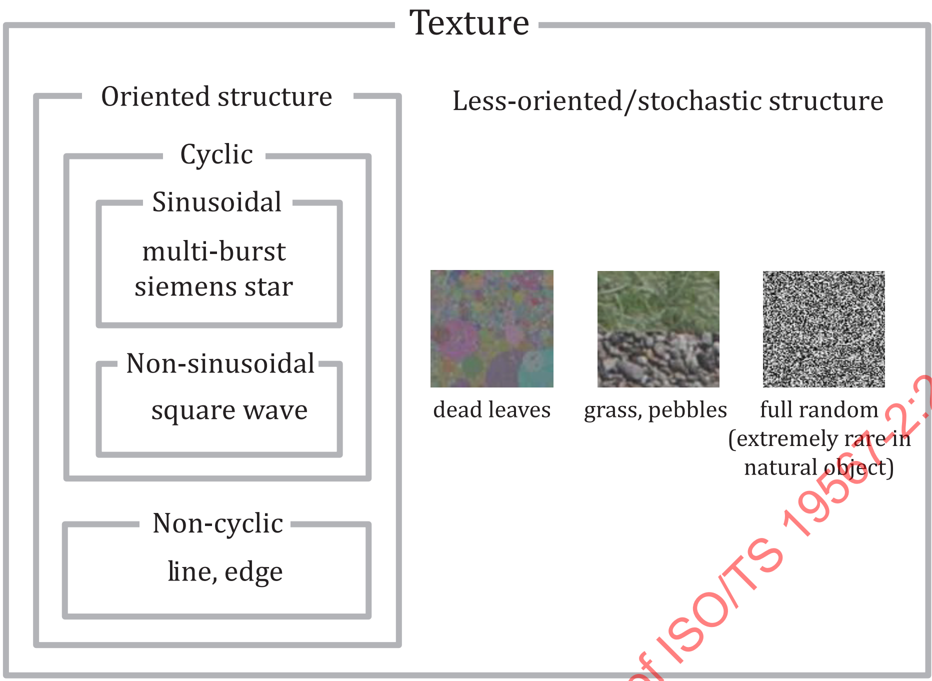


Figure A.1 — Categorization of texture

Annex B
(informative)

Exposure condition for the measurement

This annex is provided in order to explain the concept of the exposure conditions which is specified in 4.4.4.

The frequency characteristics of the output image for low contrast charts are dependent on the input amplitude to the image processing of the camera because the input signals are enhanced or reduced nonlinearly by the noise reduction etc. depending on the amplitude and the frequency. The exposure value of the camera directly influences the input amplitude for the low contrast chart so the exposure condition influences the result of the texture reproduction measurement. Lower exposure tends to give worse texture reproduction because the smaller amplitude with high frequency is often reduced by the noise reduction. In order to give a fair comparison among multiple cameras, the exposure condition is limited in the range between +5 % and −10 % of the target exposure.

Figure B.1 and Figure B.2 show how the input amplitude and output Y value are influenced by the exposure which varies from +5 % to −10 % of the target exposure when the output colour space is sRGB 8-bit (see IEC 61966-2-1:1999, 5.3 and IEC 61966-2-1/Amd 1:2003, F.5). As shown in Figure B.1 and Figure B.2, the input amplitude is proportional to the exposure and the output Y value varies depending on the exposure. The output Y value for the 18 % grey is 118 (8-bit) for the target exposure and it varies from 120 (8-bit) to 112 (8-bit) for the exposure between +5 % and −10 % of the target exposure. Thus the output Y value for the 18 % grey is specified in the range shown in 4.4.4.

	Reflectance	target exposure	output Y value of sRGB 8-bit	target exposure ×1.05	output Y value of sRGB 8-bit	target exposure ×0.90	output Y value of sRGB 8-bit
	000	0000	0	0000	0	0000	0
	001	0010	25	0011	26	0009	24
	002	0020	39	0021	40	0018	36
	003	0030	48	0032	50	0027	46
	004	0040	56	0042	58	0036	53
	005	0050	63	0053	65	0045	60
	006	0060	69	0063	71	0054	66
	007	0070	75	0074	77	0063	71
	008	0080	80	0084	82	0072	76
dark bottom (9%)	009	0090	85	0095	87	0081	80
	010	0100	89	0105	91	0090	85
	011	0110	93	0116	95	0099	89
	012	0120	97	0126	99	0108	92
	013	0130	101	0137	103	0117	96
	014	0140	105	0147	107	0126	99
	015	0150	108	0158	111	0135	103
	016	0160	111	0168	114	0144	106
	017	0170	115	0179	117	0153	109
18% gray	018	0180	118	0189	120	0162	112
	019	0190	121	0200	123	0171	115
	020	0200	124	0210	126	0180	118
	021	0210	126	0221	129	0189	120
	022	0220	129	0231	132	0198	123
	023	0230	132	0242	135	0207	126
	024	0240	134	0252	137	0216	128
	025	0250	137	0263	140	0225	130
	026	0260	139	0273	143	0234	133
bright peak (27%)	027	0270	142	0284	145	0243	135
	028	0280	144	0294	148	0252	137
	029	0290	147	0305	150	0261	140
	030	0300	149	0315	152	0270	142
	031	0310	151	0326	155	0279	144
	032	0320	153	0336	157	0288	146
	033	0330	155	0347	159	0297	148
	034	0340	158	0357	161	0306	150
	035	0350	160	0368	163	0315	152
	036	0360	162	0378	165	0324	154
	037	0370	164	0389	167	0333	156
	038	0380	166	0399	169	0342	158
	039	0390	168	0410	171	0351	160
	040	0400	170	0420	173	0360	162
	041	0410	172	0431	175	0369	164
	042	0420	173	0441	177	0378	165
	043	0430	175	0452	179	0387	167
	044	0440	177	0462	181	0396	169
	045	0450	179	0473	183	0405	171
	046	0460	181	0483	185	0414	172
	047	0470	182	0494	186	0423	174
	048	0480	184	0504	188	0432	176
	049	0490	186	0515	190	0441	177
	050	0500	188	0525	192	0450	179
	051	0510	189	0536	193	0459	180
	052	0520	191	0546	195	0468	182
	053	0530	192	0557	197	0477	184
	054	0540	194	0567	198	0486	185
	055	0550	196	0578	200	0495	187
	056	0560	197	0588	202	0504	188
	057	0570	199	0599	203	0513	190
	058	0580	200	0609	205	0522	191
	059	0590	202	0620	206	0531	193
	060	0600	203	0630	208	0540	194
	061	0610	205	0641	209	0549	196
	062	0620	206	0651	211	0558	197
	063	0630	208	0662	212	0567	198
	064	0640	209	0672	214	0576	200
	065	0650	211	0683	215	0585	201
	066	0660	212	0693	217	0594	203
	067	0670	214	0704	218	0603	204
	068	0680	215	0714	220	0612	205
	069	0690	216	0725	221	0621	207
	070	0700	218	0735	223	0630	208
	071	0710	219	0746	224	0639	209
	072	0720	221	0756	225	0648	211
	073	0730	222	0767	227	0657	212
	074	0740	223	0777	228	0666	213
	075	0750	225	0788	230	0675	214
	076	0760	226	0798	231	0684	216
	077	0770	227	0809	232	0693	217
	078	0780	229	0819	234	0702	218
	079	0790	230	0830	235	0711	219
	080	0800	231	0840	236	0720	221
	081	0810	232	0851	237	0729	222
	082	0820	234	0861	239	0738	223
	083	0830	235	0872	240	0747	224
	084	0840	236	0882	241	0756	225
	085	0850	237	0893	243	0765	227
	086	0860	239	0903	244	0774	228
	087	0870	240	0914	245	0783	229
	088	0880	241	0924	246	0792	230
	089	0890	242	0935	248	0801	231
	090	0900	243	0945	249	0810	232
	091	0910	245	0956	250	0819	234
	092	0920	246	0966	251	0828	235
	093	0930	247	0977	252	0837	236
	094	0940	248	0987	254	0846	237
	095	0950	249	0998	255	0855	238
	096	0960	250	1008	255	0864	239
	097	0970	252	1019	255	0873	240
	098	0980	253	1029	255	0882	241
	099	0990	254	1040	255	0891	242
	100	1000	255	1050	255	0900	243

Input Amplitude = 0.270-0.090 = 18%

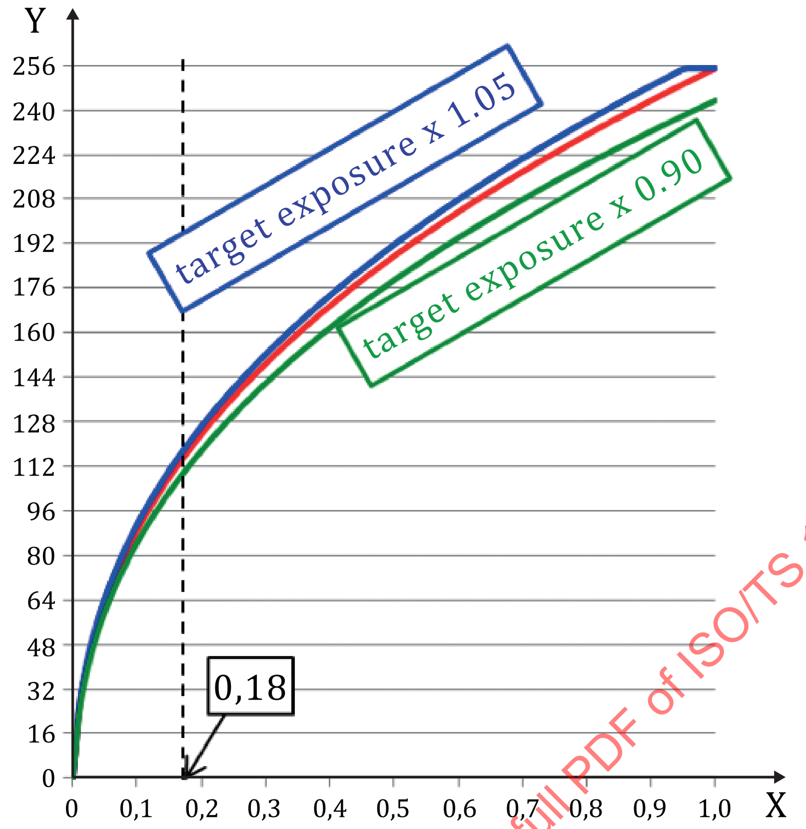
Input Amplitude = 0.284-0.095 = 19%

Input Amplitude = 0.241-0.081 = 16%

118 - 6

118 + 2

Figure B.1 — Input amplitude and output Y value depending on the exposure



Key

X reflectance of the test chart

Y output Y value for sRGB 8-bit colour space

Figure B.2 — Output Y value for sRGB 8-bit colour space