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Photography — Electronic still-picture imaging — Noise measurements

Photographie — Imagerie des prises de vue électroniques — Mesurages du bruit

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Contents

Page

Foreword

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

This second edition cancels and replaces the first edition (ISO 15739:2003), which has been technically revised.

Introduction

Noise is an important attribute of electronic photographic systems. The camera noise measurements described in this International Standard are performed in the digital domain, using digital analysis techniques. Since the noise performance of an image sensor may vary significantly with exposure time and operating temperature, these operating conditions are specified. The visibility of noise to human observers depends on the magnitude of the noise, the apparent tone of the area containing the noise and the spatial frequency of the noise. The magnitude of the noise present in an output representation depends on the noise present in the stored image data and the contrast amplification or gain applied to the data in producing the output. The noise visibility is different for the luminance (or monochrome) channel and the colour (or colour difference) channels. Therefore, this International Standard accounts for these factors in measuring and reporting the camera noise measurements. Annex A specifies the method for determining the components of the digital camera noise from a number of samples. The perceptibility of noise in an image can vary depending on the viewing distance, spatial frequency, density, colour and viewing conditions. Annex B describes a procedure for measuring the visual noise level using a human visual model as a method for weighting the spectral components of the noise. A method for removing low frequency variations in the patch data resulting, for example, from luminance shading is given in Annex C. A recommended step-by-step procedure for determining the signal to noise ratio and incremental gain is provided in Annex D. In Annex E recommendations for practical viewing conditions for various output media are given.

Photography — Electronic still-picture imaging — Noise measurements

1 Scope

This International Standard specifies methods for measuring and reporting the noise versus signal level and dynamic range of digital still cameras. It applies to both monochrome and colour electronic digital still cameras.

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 7589:2002, *Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer*

ISO 12232:2006, *Photography — Digital still cameras — Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index*

ISO 14524:2009, *Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)*

ITU-R BT.709-5, *Parameter values for the HDTV Standards for production and International programme exchange*

CIE 15:2004, *Colorimetry*, 3rd edition

3 Terms and definitions

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

3.1
camera opto-electronic conversion function
camera OECF
relationship between the input scene log luminances and the pixel values for an opto-electronic digital capture system

Note 1 to entry: The units of measurement for this function are $\log_{10}$ candelas per square metre.

3.2
clipping value
pixel value that remains constant for further increases in exposure (highlight clipping value) or for further decreases in exposure (dark clipping value)

3.3
digital still camera
DSC
camera that produces a digital still image from the digitized output of a solid-state photo sensor and records the digital still image using a digital memory, such as a removable memory card

3.4
image sensor
electronic device which converts incident electromagnetic radiation into an electronic signal

Note 1 to entry: A charge coupled device (CCD) array is an example of an image sensor.

3.5
incremental gain function
incremental gain
change in the pixel values of the DSC divided by the change in the exposure values

Note 1 to entry: For the determination of incremental gain values, log input values are not used.

Note 2 to entry: If the input exposure points are very finely spaced and the output noise is small compared to the quantization interval, the incremental gain function can have a jagged shape. Such behaviour is an artefact of the quantization process and is removed by using an appropriate smoothing algorithm, or by fitting a smooth curve to the data. In some cases, it may be desirable to fit a curve to the input-output data and then determine the incremental gain function by taking the first derivative of the function used for the curve fit.

3.6
incremental output signal
exposure level multiplied by the incremental gain at that particular exposure level

3.7
incremental signal-to-noise ratio
ratio of the incremental output signal to the root mean square (rms) noise level, at a particular signal level

Note 1 to entry: This is typically expressed as a graph or Table showing the incremental signal-to-noise ratio versus input signal level for the full range of input signal levels.

3.8
DSC dynamic range
ratio of the maximum exposure level that provides a pixel value below the highlight clipping value to the minimum exposure level that can be captured with an incremental signal-to-temporal-noise ratio of at least 1, as determined in accordance with ISO 15739

3.9
noise
unwanted variations in the response of an imaging system

3.9.1
total noise
all the unwanted variations, consisting of pattern noise and temporal noise, of the values in the digitized output captured by a single exposure

Note 1 to entry: The procedure in this International Standard for calculating the total noise requires multiple frames.

3.9.2
fixed pattern noise
unwanted variations of the values in the digitized output which remain constant between exposures

3.9.3
temporally varying noise
unwanted variation in the values of the digitized output that changes from one exposure to the next due to sensor dark current, photon shot noise, analogue processing and quantization

3.10
noise spectrum
curve or equation which expresses the image noise as a function of two-dimensional image spatial frequencies

3.11
focal plane opto-electronic conversion function
focal plane OECF
relationship between the input focal plane log exposures and the output pixel values for an opto-electronic digital image capture system

Note 1 to entry: The units of measurement for this function are $\log_{10}$ lux seconds.

3.12
exposure time
total time period during which the photo sensor is able to integrate the light from the scene to form an image

3.13
test density
spectrally non-selective transmittance filter used to reduce an input luminance to a predefined ratio of the unfiltered luminance

4 Test conditions

4.1 General

The following measurement conditions should be used as nominal conditions when measuring the noise of a DSC. 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 Illumination

4.2.1 Characteristics

The noise measurements shall indicate whether illumination conforming to the standard photographic daylight or tungsten illuminant was used. ISO 7589 describes the procedures for determining if the characteristics of the illumination used in a specific noise determination test are an acceptable match to the standard photographic daylight and tungsten illuminants.

4.2.2 Daylight illumination

For daylight measurements without the camera lens, illumination conforming to the ISO sensitometric daylight illuminant specified in Table 1 of ISO 7589:2002 shall be used. This illuminant is defined as the product of the spectral power distribution of CIE Illuminant D55 and the spectral transmittance of the ISO standard camera lens. For measurements with the camera lens in place, the spectral characteristics of the illumination shall conform to CIE illuminant D55.

4.2.3 Tungsten illumination

For tungsten measurements without the camera lens, illumination conforming to the ISO sensitometric tungsten illuminant specified in Table 2 of ISO 7589:2002 shall be used. This illuminant is defined as the product of the average spectral power distribution of experimentally measured sources having a colour temperature of approximately 3 050 K and the spectral transmittance of the ISO standard camera lens. For measurements with the camera lens in place, the spectral characteristics of the illumination shall conform to the average spectral power distribution of experimentally measured sources having a colour temperature of approximately 3 050 K.

4.2.4 Uniformity of illumination and reflection test chart illumination geometry

The illumination should meet the uniformity requirements of the measurement procedures described in Clause 5. For reflection test charts, the sources are positioned so that the angular distribution of influx radiation is at its maximum at 45° to the test chart normal, and is negligible at angles of less than 40° or more than 50° to the normal, at any point on the test chart.

Additional shielding of the camera may be necessary to prevent stray illumination from the light sources, or from other reflections, entering the camera lens. The illuminance incident on reflection charts, or the luminance used to illuminate transmission charts, shall not vary by more than 2 % from the mean value over the surface area of the chart as defined in ISO 14524:2009.

NOTE In particular, if a transmissive chart is used, light from the chart may reflect off the camera or camera operator back to the surface of the chart and be imaged by the camera. Such reflections need to be avoided. This can be accomplished by shrouding the camera with black cloth and having the operator stand in a position that avoids such reflections.

4.2.5 Light source amplitude variations

The light source shall be fixed level with combined short-term and supply amplitude variations of less than ± 2 %.

4.3 Temperature and relative humidity

The ambient room temperature during the acquisition of the test data shall be 23 °C ± 2 °C, as specified in ISO 554, and the relative humidity shall be 50 % ± 20 %. Additional measurements at 0 °C and 40 °C are recommended. The normal camera operating temperature (internal rise above ambient) shall be achieved before beginning the tests. If the ambient temperature varies throughout the room, for example as a result of heat generated by light sources, the ambient room temperature shall be measured at a distance of between 0,1 m and 0,2 m from the camera under test at the same height.

4.4 White balance

For a colour camera, the camera white balance shall be adjusted, if possible, to provide proper white balance (equal RGB signal levels) for the illumination light source, as specified in ISO 14524.

4.5 Infrared (IR) blocking filter

If required, an infrared blocking filter shall be used, as specified in ISO 14524.

4.6 Photosite integration time

The photosite integration time should not be longer than 1/30 s.

4.7 Colour noise weighting

For colour cameras using a single exposure process, the camera noise may be determined using a weighted sum of the colour outputs to derive the luminance. If the proper luminance weighting values for the RGB channel spectral sensitivities are known, they shall be used to calculate the luminance channel data. If these values are not known, the following weighting, given in ITU-R BT.709, shall be used:

$$Y = 0{,}2125\ R + 0{,}7154\ G + 0{,}0721\ B \tag{1}$$

For colour cameras with luminance and colour-difference outputs, the standard deviation of the camera noise may be computed from the luminance channel standard deviation σ (Y), the red minus luminance channel standard deviation σ (R-Y) and the blue minus luminance channel standard deviation σ (B-Y). The following Formula (2), as specified in 6.3.3 of ISO 12232:2006 shall be used:

$$\sigma(D) = [\sigma(Y)^2 + 0{,}279\,\sigma(\text{R-Y})^2 + 0{,}088\,\sigma(\text{B-Y})^2]^{1/2} \qquad (2)$$

NOTE The coefficients of the chrominance variances, σ (R-Y) and σ (B-Y), in Formula (2) were updated in this International Standard due to new coefficients being introduced in ISO 12232:2006. The revision of the coefficients was necessary due to a revised experimental procedure that indicated that the original values for the coefficients overemphasized the contribution of chrominance noise to perception.[4]

4.8 Compression

If the DSC includes any form of lossy compression, the compression shall be disabled, if possible, during the noise measurements. If the compression cannot be turned off, then measurements should be taken and the compression level reported with the noise measurement result, for example, the actual camera switch setting (fine, standard, etc.) and the approximate average number of bits per pixel.

5 Noise measurement procedures

5.1 General

These measurement procedures shall be used to determine the noise, the midtone signal-to-noise ratio and the dynamic range. The minimum requirement is to specify the midtone signal-to-total-noise ratio and the dynamic range of the digital camera under test. In addition, the fixed pattern and temporal noise components can be expressed individually. The measurement of visual noise defined in Annex B shall not be performed and reported in place of the midtone signal-to-total noise ratio. It may, however, be performed and reported together with the midtone signal-to-total-noise ratio.

NOTE The noise measurement procedures described in this International Standard are intended to measure the temporal and fixed pattern noise standard deviations spatially over the image. They do not take into account the variation in the mean pixel value between individual frames captured by a DSC. This type of frame to frame variation in mean pixel value may be introduced due to changes in ambient temperature, camera power supply or lighting flicker. The illumination and temperature requirements specified in the standard will minimize these variations. If it is required to include the effects of frame to frame variations in the calculation of temporal noise standard deviation then the standard deviation of individual pixel values needs to be calculated across multiple frames.

5.1.1 Uniform field noise measurement methods

The method of measuring the uniform field noise will be dependent on the type of camera and its level of exposure automation. If the camera lens can be removed, then the sensor noise level can be measured without any shading effects from the lens. The noise measurement procedures for DSCs having removable lenses or manual exposure control are described in 5.2 and 5.3 respectively.

On automatic exposure cameras having through the lens (TTL) exposure control and no manual exposure control override capability, the test chart and measurement methods described in 5.4 shall be used.

5.1.2 Test densities

For the noise measurement procedures described in 5.2 and 5.3 a set of test densities shall be used to provide signal levels to determine the camera OECF. The densities should correspond to the densities of the patches from a test chart specified in ISO 14524. The density of the lightest patch shall provide a signal level that is at or above the maximum unclipped level from the camera. The density of the darkest patch should be greater than or equal to 2,0. If the density of the darkest patch is less than 2,0, then a test density of 2,0 (1 % transmittance) shall be used to provide a “black reference” signal level to determine the camera dynamic range.

5.1.3 Adjustment of illumination, test density placement and camera lens focus

The light source and diffuser (where applicable) shall be adjusted to give the maximum unclipped level from the camera. If necessary, an appropriate neutral density filter should be used to cover the camera exposure control sensor in order to adjust the signal level to provide the maximum unclipped level from the camera. In some circumstances it may not be possible to reach the maximum unclipped level due to the limitations in the resolution of the exposure adjustment or in the light source used. In this case expose the uniform field in such a way that the exposure is increased by the smallest possible step from the exposure leading to the maximum unclipped level so that the output signal is "just clipped".

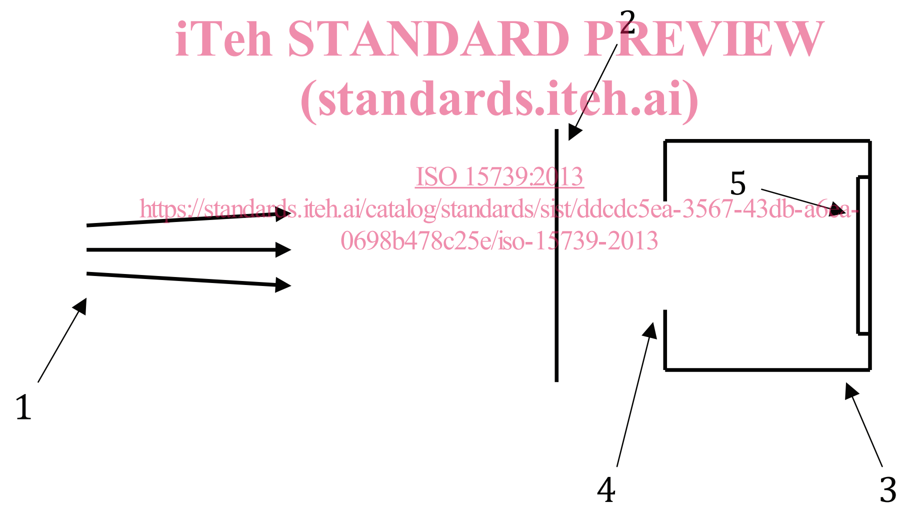
Test densities (when used) shall completely cover the area exposed, when the camera lens is removed.

If the camera lens focus is adjustable, it shall be set to infinity.

5.2 Measurement of a DSC having a removable lens

5.2.1 General

This method involves the exposure of the DSC sensor directly to specific quantities of uniform illumination with the lens removed. The illumination shall have the spectral characteristics specified in 4.2 and shall be produced by a small source at a distance, such that the largest dimensions of the source and the sensor are no greater than one twentieth of the distance between them, as shown in Figure 1. Reflective surfaces shall not be placed where they could cause additional illumination to be incident on the sensor.



Key

1 light source
2 test density
3 camera under test
4 lens removed
5 digital image sensor

Figure 1 — Illumination for cameras with removable lenses

5.2.2 The focal plane OECF shall be measured according to ISO 14524.