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ISO TC 42~~/WG 18~~

Date: 2023-~~01-23~~xx

Secretariat: ANSI

Photography — Electronic still picture imaging — Noise measurements

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

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Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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~~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~~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 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~~www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 15739:2017), which has been technically revised.

The main changes are as follows:

— several terms and definitions have been modified, added, and deleted (see Clause 3);

— calculation procedures of camera noise, signal-to-noise ratios, and DSC dynamic range have been revised for measurement accuracy (see Clause 6);

— presentation of results has been specified expressly (see Clause 7);

— description of noise component analysis has been revised to be more detailed (see Annex A);

— measurement method of visual noise has been revised to model the human visual system more closely (see Annex B);

— method for removing low frequency variations from the image signals has been revised and changed from informative to normative processing (see Annex C);

— description of procedure for determining signal-to-noise ratio has been revised (see Annex D);

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— introduction of perceptually uniform mapping of visual noise to noisiness JND has been added (see Annex F).

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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.htmlwww.iso.org/members.html.

Introduction

Noise is an important attribute of electronic still-picture imaging. If noticeable levels of noise exist in the images captured by a camera, then detail textures of objects are lost in reproduction and the visibility of the images is degraded. Therefore, measurement methods for noise are very important and are needed to provide important information relevant to evaluating image fidelity and the visibility of noise in captured images. Measurement methods are also important for assessing camera performance relative to these image quality factors.

The primary sources of noise in captured images are photon shot noise, dark current shot noise, analogue processing readout noise of image sensors, and quantization noise of A/D converters. This type of noise source adds spatially random noise to captured still images, whose spatial pattern differs from frame to frame. The other type of noise source includes dark current pattern noise, row/column pattern noise, and photo response non-uniformity of image sensors. This type of noise source also introduces spatially random noise in captured images; however, its spatial pattern does not change under the same shooting conditions.

The noise level introduced by these sources in output images is highly dependent on shooting conditions, such as the camera exposure time, aperture value, and ISO sensitivity. Camera operating temperature is also an influential factor. Some camera processing, such as contrast amplification and noise reduction, heavily influence the noise spectrum, in addition to the noise level itself.

The image quality metrics described in this document are determined from the measurement of spatially distributed noise in the output still image that is viewed by an observer. The metrics include the effect of the internal camera processing on the distribution and level of the noise.

When observers view output images, several factors affect how they perceive noise in images, in addition to the noise level itself. Observers view noise differently depending on the apparent tone of the area being viewed, the luminance and colour channels where noise exists, the noise spectrum, and the viewing conditions.

This document specifies methods for measuring noise and related metrics of digital still cameras accounting for these influential factors. Measurement conditions are specified to minimize the influence of disturbance factors, to ensure that temporal and spatial statistical property changes are negligible, and to provide a good estimate of the noise level.

The main body of this document specifies methods for measuring input-referred noise, signal-to-noise ratios, and DSC dynamic range. Noise is determined as an estimate of the perceived noise computed using root mean square values measured in image signals linearized from the camera output signals. The two types of spatially random noise, temporal and fixed pattern, are determined using a noise component analysis applied to multiple captured images, the details of which are provided in Annex A.

Annex B describes a procedure for measuring the visual noise (an output-referred noise metric) using a human visual model that aims to predict the perceived quality of the image. The model weights spectral components of the noise and takes into account the noise spectrum, viewing conditions, and the perceived difference between luminance and colour channels. The metric has been shown to provide a high level of correlation with human perception of noise in images.

Low frequency variations may be introduced in the captured image due to lens shading and non-uniform test chart illumination. Since these variations can influence the noise measurement a method for removing low frequency variations from the image is provided in Annex C.

Annex D provides a recommended step-by-step procedure for determining the signal-to-noise ratio.

Annex E describes recommendations for practical viewing conditions for various output media.

Annex F introduces perceptually uniform mapping of visual noise to noisiness JND.

Photography — Electronic still picture imaging — Noise measurements

1 Scope

This document 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 are referred to in the text in such a way that some or all of their content constitutes requirements 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.

~~<std>~~ISO 554, *Standard atmospheres for conditioning and/or testing — Specifications*~~</std>~~

~~<std>~~ISO 7589:2002, *Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer*~~</std>~~

~~<std>~~ISO 12232:2019, *Photography — Digital still cameras — Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index*~~</std>~~

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

~~<std>~~ITU-R BT.709-6, *Parameter values for the HDTV Standards for production and International programme exchange*~~</std>~~

~~<std>IEC 61966-2-1:1999~~IEC 61966-2-1, *Multimedia systems and equipment — Colour measurement and management*~~—~~ *— Part 2-1: Colour management — Default RGB colour space — sRGB*~~</std>~~

~~<std>IEC 61966-2-1:1999/AMD1:2003, Amendment 1~~ IEC 61966-2-1/Amd.1:2003, *Multimedia systems and equipment — Colour measurement and management* ~~—~~ *— Part 2-1: Colour management — Default RGB colour space — sRGB*~~</std>~~ *— Amendment 1*

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 ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

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

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Note 1 to entry: The unit of luminance (L) is cd/m². Log luminance is dimensionless, expressed as $\log_{10}(L/L_0)$, where L_0 = 1 cd/m².

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
DSC dynamic range
ratio of the input signal (luminance or exposure) saturation level to the minimum input signal level that can be captured with a signal-to-temporal noise ratio of at least 1~~, as determined in accordance with ISO 15739~~

Note 1 to entry: Determined in accordance with ISO 15739.

3.5
exposure time
total time period during which the photo sensor is able to integrate the light from the scene to form an image

3.6
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 unit of exposure (H) is lx·s. Log exposure is dimensionless, expressed as $\log_{10}(H/H_0)$, where H_0 = 1 lx·s.

3.7
image sensor
electronic device which converts incident electromagnetic radiation into an electronic signal

Note 1 to entry: A complementary metal oxide semiconductor (CMOS) image sensor and a charge coupled device (CCD) image sensor are examples of image sensors.

3.8
noise
unwanted variations in the response of an imaging system

3.8.1
total noise
all the unwanted variations, consisting of *fixed pattern noise* (3.8.2) and *temporal noise* (3.8.3), of the values in the image signals captured by a single exposure

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

3.8.2
fixed pattern noise
FPN
unwanted spatial pixel variations of the values in the image signals which remain constant from frame to frame given the same illumination, aperture value, integration time, and ISO sensitivity setting

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Note 1 to entry: Most fixed pattern noise (FPN) varies in digital number with sensor gain and ISO sensitivity setting and cannot, therefore, be considered static relative to exposure. There are three classes of fixed pattern noise, (1) static with integration time, for example, pixel FPN, column FPN and row FPN, (2) varies with integration time, for example dark current FPN, but static from frame to frame, and (3) signal dependent FPN such as photo response non-uniformity (PRNU), but still static from frame to frame.

Note 2 to entry: PRNU is a pixel to pixel gain mismatch. It is normally expressed as a percentage of signal because it is a gain error. It is static from frame to frame and, thus, contributes to fixed pattern noise but its magnitude is a function of signal level. It is, therefore, considered as a signal dependent FPN.

3.8.3
temporally varying noise
temporal noise
unwanted variation in the values of the image signals that changes from frame to frame due to sensor dark current shot noise, photon shot noise, analogue processing, and quantization

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3.9
noise spectrum
curve or equation which expresses the image noise as a function of two-dimensional image spatial frequencies

3.10
saturation
condition where the camera output signal reaches the maximum valid (not clipped or bloomed) value

3.10.1
exposure saturation
minimum focal plane exposure that produces the maximum valid (not clipped or bloomed) camera output signal

Note 1 to entry: The exposure saturation is expressed in lux-seconds (lx·s).

3.10.2
luminance saturation
minimum scene luminance that produces the maximum valid (not clipped or bloomed) camera output signal

Note 1 to entry: The luminance saturation is expressed in candelas per square meter (cd/m^2).

Note 2 to entry: The luminance saturation is determined for a fixed exposure setting of the camera under test.

3.11
signal-to-noise ratio
ratio of the input signal (luminance or exposure) level to the root mean square (rms) noise level, at a particular signal level

Note 1 to entry: In this document, the output pixel value is converted to an input signal level by applying the inverse OECF. The average of the input signal levels corresponds to the scene luminance (focal plane exposure) value when capturing an image. Unwanted variations exist in the converted input signal level that are centred about its average. This variation in input signal level is noise and is measured as the rms value.

Note 2 to entry: This is typically expressed as a graph or table showing the signal-to-noise ratio versus input signal level for the full range of input signal levels.

3.12
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 ISO 7589:2002, Table 1 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 ISO 7589:2002, Table 2 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.

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NOTE In particular, if a transmissive chart is used, light from the chart can 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.

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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.

NOTE In the visual noise measurement specified in Annex B, a colour cast can result in some errors being introduced into the calculation of visual noise values.

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4.5 Infrared (IR) blocking filter

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

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4.6 Photosite integration time

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

4.7 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 DSC dynamic range. The method of measuring noise on the spatially uniform field (luminance or exposure) will be dependent on the type of camera and its level of exposure automation.

On all cameras, the test chart and measurement methods described in 5.2 shall be used except in the following cases.

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