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Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)

Photographie — Appareils de prises de vue électroniques — Méthodes de mesure des fonctions de conversion opto-électroniques

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 734 10 79
E-mail copyright@iso.ch
Web www.iso.ch

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14524 was prepared by Technical Committee ISO/TC 42, *Photography*.

Annex A forms a normative part of this International Standard. Annexes B to C are for information only.

Introduction

This International Standard was prepared by Technical Committee ISO/TC 42, *Photography*, Working Group 18, *Electronic still picture imaging*. It establishes standard methods for measuring the functional relationship between the focal-plane log exposures or scene luminances, and the digital output levels of a digital camera. This information is required for the development and testing of digital cameras, is used in other electronic still-picture camera measurement standards, and may be helpful in the processing of digital image data.

An opto-electronic conversion function (OECF) measurement standard is required for several reasons.

a) Well-established measurement methods have been used to determine the characteristic curves for television cameras, where the characteristic curve is known as the "gamma correction" curve, and for silver halide photography, where the characteristic curve is known as the "H&D" or "DlogH" curve. However, these methods cannot be easily or unambiguously applied to the characterization of electronic still-picture cameras.

b) The sampling and quantization processes found in digital systems present fundamental issues that need to be addressed in a standardized manner.

c) The flexibility of digital systems complicates the determination and presentation of the functional relationship between the camera's optical input and digital output levels. This International Standard attempts to account for all the variables and assure that results are presented in a consistent fashion.

The OECF of a digital camera may appear to be the analogue of the characteristic curve used in photography and television, but this observation is only partly true. Characteristic curves show the relationship between a physical input, such as log exposure or reflectance, and a physical output, such as density or volts. The OECF, on the other hand, shows the relation between a similar physical input and a digital code value assigned to the physical response produced by that input. Since this assignation can be arbitrary, digital values themselves do not have physical meaning or units. For example, a change of a factor of two in digital values could correspond to a doubling of the physical response to the input, to an order of magnitude change, or to something else, depending on how the code values are assigned.

In digital photography applications, it is generally not necessary to know the physical response produced in a digital camera. It is sufficient to know what digital values will be produced by a variety of inputs. Consequently, this International Standard does not specify how to measure the true characteristic curve of a digital camera. Rather, it specifies how to measure the relationship between the input to a digital camera and the digital code values produced. These values are only absolutely meaningful in that they represent information. The graphical reporting formats specified in this International Standard support this viewpoint by allowing OECFs to be reported with either digital code values or bits on the vertical axis. This is the convention in information theory. Users of this International Standard should be aware that the actual physical response of a digital camera, or of a complete digital photography system, can be linear, logarithmic, or something else, regardless of the form of the OECF plot and whether digital code values or bits are reported on the vertical axis.

NOTE Users of this International Standard in English-speaking countries should be aware that commas are used instead of periods as the decimal radix to conform to ISO procedures.

Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)

1 Scope

This International Standard specifies methods for the measurement of opto-electronic conversion functions (OECFs) of electronic still-picture cameras whose output is encoded as a digital image file. The OECF is defined as the relationship between the focal plane log exposures or scene log luminances, and the digital output levels of an opto-electronic digital image capture system.

This International Standard applies to both monochrome and colour electronic still-picture cameras.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5-1:1984, *Photography — Density Measurements — Part 1: Terms, symbols and notations.*

ISO 5-2:1991, *Photography — Density Measurements — Part 2: Geometric conditions for transmission density.*

ISO 5-3:1995, *Photography — Density Measurements — Part 3: Spectral conditions.*

ISO 5-4:1995, *Photography — Density Measurements — Part 4: Geometric conditions for reflection density.*

ISO 516:1999, *Photography — Camera shutters — Timing.*

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications.*

ISO 7589:1984, *Photography — Illuminants for sensitometry — Specifications for daylight and incandescent tungsten.*

3 Terms and definitions

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

3.1
camera opto-electronic conversion function
camera OECF
relationship between input scene log luminances (units: $\log_{10}$ candela per square metre) and digital output levels for an opto-electronic digital image capture system

See **opto-electronic conversion function** (3.11)**, focal plane opto-electronic conversion function** (3.5)

3.2
digital output level
digital code value
numerical value assigned to particular output level or range of output levels in a digital system

3.3
electromechanical shutter
mechanical shutter which is electronically controlled

3.4
electronic still-picture camera
camera incorporating an image sensor which outputs an analog or digital signal representing a still picture, or records an analog or digital signal representing a still picture on a removable media, such as a memory card or magnetic disk

3.5
focal plane opto-electronic conversion function
focal plane OECF
relationship between input focal plane log exposures (units: $\log_{10}$ lux seconds) and digital output levels for an opto-electronic digital image capture system

See **opto-electronic conversion function** (3.11)**, camera opto-electronic conversion function** (3.1)

3.6
incremental gain function
rate of change in output level (digital code value) divided by rate of change in input level (luminance or exposure) as a function of input level

NOTE 1 For the determination of incremental gain values, log input values are not used.

NOTE 2 If the input exposure points are very finely spaced and the output noise is small compared to the quantization interval, the incremental gain function may have a jagged shape. Such behaviour is an artifact of the quantization process and should be 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.

3.7
incremental output signal
input level (luminance or exposure; not logged) multiplied by the system incremental gain at that level

See **incremental gain function** (3.6)

3.8
illuminance scale exposure series
series of exposures produced using constant exposure time and varying focal plane illuminance

See **time scale exposure series** (3.15)

3.9
maximum exposure limit
smallest exposure which produces the digital output level corresponding to the maximum detectable exposure which is also known as the saturation or quantization ceiling

See **minimum exposure limit** (3.10)

3.10
minimum exposure limit
largest exposure below saturation which produces an incremental output signal equal in magnitude to output noise

See **incremental output signal** (3.7), **maximum exposure limit** (3.9), **output noise** (3.13)

3.11
opto-electronic conversion function
OECF
relationship between log of input levels and corresponding digital output levels for an opto-electronic digital image capture system

NOTE If the input log exposure points are very finely spaced and the output noise is small compared to the quantization interval, the OECF may have a step-like character. Such behaviour is an artifact of the quantization process and should be removed by using an appropriate smoothing algorithm or by fitting a smooth curve to the data.

3.12
opto-electronic digital image capture system
system which converts either light exposure at the focal plane, or spatial arrangement of luminances (a scene) to digital information

3.13
output noise
root-mean-square fluctuation about mean in the digital output level for constant input level

3.14
scene luminance ratio
ratio of highest (highlight) luminance value to lowest (shadow) luminance value in scene

3.15
time scale exposure series
series of exposures produced using constant focal plane illuminance and varying exposure time

See **illuminance scale exposure series** (3.8)

3.16
white balance
adjustment of electronic still-picture colour channel gains or image processing so that radiation with relative spectral power distribution equal to that of the scene illumination source is rendered as a visual neutral

NOTE Additional definitions of interest may be found in ISO 12232.

4 Test methods

4.1 General information

This International Standard describes test methods for measuring both camera OECFs and focal plane OECFs. Camera OECFs include the effects of the camera lens and associated flare, while focal plane OECFs do not. These image-formation effects vary with the overall scene luminance ratio, the amounts of each of the different luminances present in the scene, and the spatial arrangement of these luminances. This variability can be quite large, and consequently it is possible to determine a repeatable camera OECF only for a specific scene, such as a test chart. The camera OECF measurement method described in this International Standard allows for the determination of different camera OECFs based on test charts with different luminance ratios, but does not allow for the effects of different amounts or spatial arrangements of scene luminances. The camera OECF test charts are designed to simulate the image formation effects produced by a scene with a specific luminance ratio and average distribution of luminances; however many scenes are significantly different from average. When determining camera OECFs, it is important to keep in mind that the OECF characteristics measured may be quite different from those exhibited by the camera in capturing specific scenes. The reasons for inclusion of a camera OECF measurement method are as follows:

a) the mandatory automatic exposure control found in some cameras precludes the determination of focal plane OECFs;

b) the camera OECF measurement method allows for one-step determination of the camera system characteristics for the scene simulated by the test chart used;

c) focal plane OECF values can be estimated from camera OECF values for the midtone and highlight regions of most images, provided that the range of interest is covered by the test chart used.

The focal plane OECF is a characteristic of the camera only, and is not dependent on the scene.

NOTE Some cameras and/or supporting software may contain scene-dependent rendering algorithms. These algorithms are generally bypassed when performing focal plane OECF measurements because of the approximately uniform illumination incident on the focal plane. In situations where it is impossible or undesirable to bypass the rendering algorithms, it is more appropriate to perform camera OECF measurements.

Two methods are described for focal plane OECF measurement, although both methods should give the same result. The preferred method (method A) allows for a higher degree of accuracy than the alternative method (method B). Method B should be used only with cameras that have fixed lenses. The advantages of focal plane OECFs are the following.

a) Separation of the optical image formation stage from the focal plane image to output stage allows each stage of the image capture to be dealt with independently. These two stages behave quite differently. The image formation stage is strongly scene dependent, while the focal plane image to output stage depends only on the sensor and camera electronics' characteristics. On the other hand, the response of pictorial cameras tends to be highly non-linear, complicating the subsequent analysis of optical image formation effects if the focal plane OECF is not known. The analysis of camera systems is much easier if the two stages are dealt with independently.

b) Traditionally, only the density vs. log exposure relation, or characteristic curve, is measured for film. This curve is analogous to the focal plane OECF.

c) The predominant factor affecting camera OECF values in the darker areas of a scene is the camera flare. These values are, therefore, primarily scene dependent, and do not provide much information about the general camera characteristics.

d) Focal plane OECFs cover the entire usable range of the camera, and are not limited by the test-chart luminance ratio.

The methods for measurement of the OECFs described above are given in 4.2 to 4.4.

4.2 Camera OECF measurement

The OECF may be determined for the entire opto-electronic digital image capture system of the camera, using the ISO camera OECF test chart. This determination is accomplished by using the camera system to capture an image of the chart under controlled conditions. It should be noted that the independent variable for the camera OECF is scene log luminance, not focal plane log exposure as with the focal plane (method A) and alternative focal plane (method B) measurement methods.

4.3 Focal plane OECF measurement (method A)

Method A involves the exposure of the electronic still-picture camera sensor directly to specific quantities of uniform illumination with the camera lens removed. The illumination shall have the spectral characteristics specified in section 5.1, 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 1/20 of the distance from the source to the sensor. Also, reflective surfaces shall not be placed where they could cause additional illumination to be incident on the sensor.

4.4 Alternative focal plane OECF measurement (method B)

If a particular electronic still-picture camera does not allow the lens to be removed, method B may be employed. This method involves the use of a uniformly emissive, approximately Lambertian target (reflective surface or illuminator), which is then imaged by the camera lens on the sensor. If method B is used, the sensor illuminance shall be assumed to be as calculated from the following equation (see [9] in the bibliography).

$$E_{\mathrm{s}} = \frac{0{,}65\, L_{\mathrm{t}}}{f_{\mathrm{e}}^{2}} \qquad (1)$$

where

E_s is the illuminance, in lux, falling on the sensor;

L_t is the arithmetic mean luminance of the target, in candelas per square metre;

f_e is the effective *f*-number of the lens.

If method B is used, the target shall be measured to verify that it is approximately Lambertian and uniform in luminance. Luminance readings of the target shall be within 2 % of the arithmetic mean value for readings taken normal to the target at all four corners and at the centre of the field of view of the camera, and also for readings taken at an angle of 30° to normal of the centre of the target. The surface of the target shall be normal to the optical axis of the camera (± 5°) when the test image is captured, and shall extend out at least 15° beyond the edge of the camera field of view. The spectral radiance characteristics of the target shall be as described in 5.2.

ISO OECFs obtained using method B shall be designated as such.

5 Illumination

5.1 Focal plane OECF measurement (method A)

OECF measurements shall indicate whether the daylight or tungsten illuminant was used. ISO 7589 specifies the procedures for determining if the illumination used for OECF measurements is an acceptable match to the daylight and tungsten sensitometric illuminants.

5.2 Alternative focal plane (method B) and camera OECF measurement

Since these test methods involve measurements with the camera lens in place, the spectral radiance characteristics of the target, for the alternative focal plane OECF, or the chart illumination source, for the camera OECF, should be equivalent to either the daylight or tungsten ISO standard source. The relative spectral power distributions for these sources are provided in the second column of Tables 1 and 2 in ISO 7589:1984. In order to apply the ISO/SDI (spectral distribution index) criterion to these sources, the spectral radiance of the source or target shall be measured and then multiplied by the relative spectral transmittance of the ISO standard lens, which is also described in ISO 7589, prior to multiplying by the weighted spectral sensitivities. See informative annex B.

With these test methods, the target or chart, and camera lens, shall be shielded from external illumination sources and reflective surfaces, including the walls, ceiling, and floor of the test room, using black shielding materials. The wall behind the target or chart shall be black, and the only illumination sources present shall be those used to illuminate the chart. For reflective targets or charts, the illumination sources shall be positioned so that the angular distribution of influx radiance is at its maximum at 45° to the target or chart normal, and is negligible at angles less than 40° or more than 50° to the normal at any point on the target or chart. ISO 12233 may be consulted for recommendations for reflection chart illumination geometries.

6 Test conditions

6.1 Temperature and relative humidity

The ambient 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) %.

6.2 White balance (only applicable to colour cameras)

6.2.1 Single fixed white-balance setting

If a camera has only one fixed white-balance setting, either in the camera circuitry or supporting software supplied with the camera, this setting shall be used for all OECF determinations and the white balance for these OECFs shall be designated as "fixed".