BRITISH STANDARD

BS ISO 14524:2009

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

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British Standards

National foreword

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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

This second edition cancels and replaces the first edition (ISO 14524:1999), which has been technically revised.

Introduction

This International Standard 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, as outlined below.

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 ensure that results are presented in a consistent fashion.

The OECF of a digital camera might 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 are advised 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 In accordance with the rules given in the ISO/IEC Directives, Part 2, commas are used rather than full-stops as the decimal radix in this International Standard.

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 referenced documents are indispensable for the application 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.

ISO 5-1, *Photography — Density measurements — Part 1: Terms, symbols, and notations*

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

ISO 5-3, *Photography — Density measurements — Part 3: Spectral conditions*

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

ISO 516, *Photography — Camera shutters — Timing*

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply[1].

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

NOTE The units of measurement for this function are $\log_{10}$ candelas per square metre.

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[1] Additional definitions of interest can be found in ISO 12232.

3.2
digital output level
digital code value

numerical value assigned to a particular output level

3.3
electromechanical shutter

mechanical shutter which is electronically controlled

3.4
electronic still-picture camera

camera incorporating an image sensor that outputs an analogue or digital signal representing a still picture and/or records an analogue or digital signal representing a still picture on a removable medium, such as a memory card or magnetic disc

3.5
focal plane opto-electronic conversion function
focal plane OECF

relationship between the input focal plane log exposures and the digital output levels for an opto-electronic digital image capture system

NOTE The units of measurement for this function are $\log_{10}$ lux seconds.

3.6
illuminance scale exposure series

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

3.7
incremental gain function

change in the output level (digital code value) divided by the change in the 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 can have a jagged shape. Such behaviour is an artefact of the quantization process and it is advisable to remove this by using an appropriate smoothing algorithm or by fitting a smooth curve to the data. In some cases, it might 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.

3.8
incremental output signal

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

3.9
maximum exposure limit

smallest exposure which produces the digital output level corresponding to the maximum detectable exposure

NOTE The maximum detectable exposure is also known as the saturation or quantization ceiling.

3.10
minimum exposure limit

largest exposure below saturation which produces an incremental output signal equal in magnitude to the output noise

3.11
opto-electronic conversion function
OECF

relationship between the log of the input levels and the 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 can have a step-like character. Such behaviour is an artefact of the quantization process and it is advisable to remove this 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 a light exposure at the focal plane, or a spatial arrangement of luminances (a scene) to digital information

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

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

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

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

4 Test methods

4.1 General

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 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 can 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 as described below.

- 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.
- Traditionally, only the density versus log exposure relation, or characteristic curve, is measured for film. This curve is analogous to the focal plane OECF.
- 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.
- 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 camera opto-electronic digital image capture system using a camera OECF test chart as defined in this International Standard. 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)

This method 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 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 the distance from the source to the sensor. In addition, 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 illuminance falling on the sensor, E_s, expressed in lux, shall be assumed to be as calculated from Equation (1) (see Reference [9]):

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

where

L_t is the arithmetic mean luminance of the target in candela 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.

OECFs obtained using method B of this International Standard 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 describes the procedures for determining whether 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 source specified in ISO 7589. The relative spectral power distributions for these sources are provided in the second column of Tables 1 and 2 in ISO 7589:2002. In order to apply the ISO 7589 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 7589 standard lens (also described in ISO 7589), prior to multiplying by the weighted spectral sensitivities. See 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 ± 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”.

6.2.2 Daylight and/or tungsten fixed white balance settings

If a camera has fixed white balance settings designated as “daylight” and/or “tungsten”, either in the camera circuitry or supporting software, the white balance adjustment may be set at either of these fixed settings. If this white balance option is chosen, the white balance for the OECF(s) determined shall be designated as “daylight” and/or “tungsten”, depending on the setting chosen.

6.2.3 Variable white balance

6.2.3.1 General

If the camera white balance can be adjusted using a variable white balance adjustment, either in the camera circuitry or supporting software, the variable white balance option may be chosen. In this case, the white balance for the OECF(s) determined shall be designated as “variable” and shall be set to provide respectively neutral digital output levels for the colour channels. Neutral digital output levels means equal Red-Green-Blue (RGB) levels, or luminance-chrominance levels indicating no chrominance.

6.2.3.2 Focal plane OECFs

The white balance shall be set to provide neutral digital output levels for a focal plane exposure which is greater than one-half of the maximum exposure limit.

6.2.3.3 Camera OECFs

The white balance shall be set to provide neutral digital output levels for the camera OECF test-chart background.

6.2.4 Automatic white balance

If a camera automatically adjusts its white balance with every exposure, the white balance for the OECFs determined shall be designated as “automatic”. It should be noted that in this case the camera OECF may provide colour information not found in the focal plane OECFs.

6.3 Infrared-blocking (IR-blocking) filter

If required, one or more IR-blocking filters shall be placed in front of the camera lens. These filters are required if the output signal level of the camera with a visible light blocking, IR-transmitting filter is greater than 5 % of the maximum digital output level, at the exposure or luminance which produces the maximum camera digital output level without the IR-transmitting filter. The IR-transmitting filter used to test to see whether an IR-blocking filter is required shall have a maximum edge (50 % transmittance) wavelength of 780 nm and a transmittance of less than 1 % at wavelengths between 350 nm and 740 nm. The IR-blocking filters should be chosen to provide the required reduction in IR sensitivity without changing the photometric sensitivity any more than absolutely necessary. If IR-blocking filters are required, the filter types used shall be indicated. The purpose of the IR-blocking filters is to prevent the OECF measurement from being significantly affected by infrared radiation.

6.4 Focus

6.4.1 Alternative focal plane OECF measurement (method B)

If the camera lens focus is adjustable, it shall be set on infinity, or the largest subject distance setting available.

6.4.2 Camera OECF measurement

The camera lens should be focused on the camera OECF test chart, such that the image produced appears reasonably sharp. The camera lens may be slightly defocused to blur high frequency noise or halftone screening present in the test chart. Focus is not critical for OECF determination, but extreme out-of-focus images of the test chart may produce erroneous results due to blurring of the patch edges.

The effective f-number, f_e, for the focused image shall be calculated as shown in Equation (2):

$$f_\mathrm{e} = \left(\frac{1}{R} + 1\right) f \tag{2}$$

where

R is the ratio of the chart height to the chart image height at the focal plane;

f is the f-number.

Supplementary lenses may also be used to produce a sharp image of the test chart. If they are used, the effective f-number shall be calculated based on the reduction ratio that would be produced with the camera lens in the same focus position, but without the supplementary lens. Any supplementary lenses used shall be large enough so that the clear aperture of the camera lens is not obstructed. If a supplementary lens is used, this fact shall be noted in the presentation of the measurement results.

7 Input

7.1 Focal plane log exposures

The sensor shall be exposed to the specified source radiation in quantities which range from the minimum to the maximum exposure limits. Time and intensity scale series are acceptable, but the OECF obtained shall be designated as a time or intensity scale function, with the exposure time and/or focal plane illuminance listed, since the noise may vary with exposure time. The input log exposure increments shall not be separated by more than one stop (one stop is equal to a factor of two or approximately 0,3 log units).

The camera shutter may be used to regulate the exposure time, but the accuracy of mechanical and electromechanical shutters shall be verified using the methods specified in ISO 516.

A minimum of nine exposure series shall be obtained and analyzed, as described in Clause 8, to ensure the reliability of the data.

7.2 Camera OECF chart log luminances

The standard camera OECF test chart shall be as described in Annex A. The preferred method for measuring the chart luminances is to use a telescopic photometer placed at the camera location. If this method is used, all areas of the chart, except for the patch being measured, shall be covered with a black mask to prevent flare in the telescopic photometer from affecting the measurements. If a telescopic photometer is not available, the chart luminances may be calculated from the chart densities and illuminance using Equations (3) and (4).

For reflection charts, the luminance L_i of the patch with density D_i, expressed in candelas per square metre, is calculated as follows:

$$L_i = \frac{10^{-D_i}\, E}{\pi} \tag{3}$$

where

D_i is the grey-scale patch visual density;

E is the illuminance incident on the chart (measured using a cosine corrected photometer), in lux.

For transmission charts, L_i is calculated as follows:

$$L_i = 10^{-D_i} L \tag{4}$$

where

D_i is the grey-scale patch visual diffuse transmission density;

L is the luminance of the diffuse illuminator on which the chart is placed, in candelas per square metre.

If the chart luminances are calculated from the chart densities, 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, and care should be taken to eliminate any specular reflection component (surface glare). Calculated chart luminances shall be reported as such when presenting camera OECF measurement results.

The surface of the chart shall be normal to the optical axis of the camera (± 5°) when the test image is captured. A minimum of nine exposures of the chart shall be obtained and analysed, as described in Clause 8, to ensure the reliability of the data. The camera exposure settings should be adjusted to produce chart background digital code values close to a midtone for the colour encoding the camera is set to produce. Auto-exposure may be used.

NOTE If the camera is set to create image data encoded as an 8 bit sRGB, a midtone will be near code value 118.

8 Data analysis

The camera digital output level data shall be analysed as described below.

A minimum of nine trials shall be conducted at each exposure level. A trial shall consist of separate exposures if a specific camera is being measured, and separate exposures with different, randomly selected cameras if the measurement is to be representative of a particular type of camera. For each trial, the mean digital output level shall be determined from a (64 × 64) pixel area located at the same relative position in each image. With the alternative focal plane OECF method (method B), the (64 × 64) pixel area shall be located at the centre of the image. The final digital output level data presented shall be the mean of the mean digital output levels for all the trials.

NOTE It is possible that with very low resolution cameras the images of the camera OECF test chart patches will not be large enough to contain a (64 × 64) pixel area. In this case, it is advisable that the sample area be slightly smaller than the image of the patch area so that the effects of imaging the patch edge are not included.

9 Presentation of results

9.1 General

The results of an OECF measurement shall be presented in tabular and/or graphical form. All log luminances and log exposures shall be to the base 10.

The table heading or figure caption shall indicate the following:

a) focal plane, alternative focal plane, or camera OECF measurement;

b) monochrome or colour capture and camera type;

c) time or illuminance scale exposure series (except for camera OECF measurements);

d) exposure time or focal plane illuminance (except for camera OECF measurements);

e) exposure time, camera lens focal length and effective *f*-number (camera OECF measurements only);

f) measured or calculated chart log luminances (camera OECF measurements only);

g) daylight or tungsten illumination;

h) fixed, daylight, tungsten, variable, or automatic white balance (for colour cameras);

i) the designation of the IR-blocking filter used (if any);

j) the designation of the supplementary lens used (if any).

9.2 Tabular presentation

9.2.1 Focal plane (method A) and alternative focal plane (method B) OECFs

This presentation gives results in a table listing the camera type, the input log exposures, the exposure time and/or focal plane illuminance and the digital output levels. If the camera system is a multi-spectral system, the digital output levels for all spectral bands shall be listed. See Table 1.

Table 1 — Example of an alternative focal plane OECF table for an electronic still-picture camera

log exposure	Mean output levels		
	Red	Green	Blue
− 3,00	7,7	8,2	10,0
− 2,70	10,6	11,9	11,8
− 2,40	16,5	17,1	15,9
− 2,10	25,6	23,0	21,2
− 1,80	39,4	32,2	27,1
− 1,50	63,5	55,2	49,4
− 1,20	97,7	85,7	78,8
− 0,90	149,1	133,4	122,1
− 0,60	205,8	191,4	180,7
− 0,30	245,4	233,0	225,0

Colour capture (single chip RGB colour filter array camera).

Time scale exposure series, focal plane illuminance 3,98 lx.

Daylight illumination, daylight white balance.

Tiffen heat mirror IR-blocking filter.

log exposure: $\log_{10}(H/H_0)$, where $H_0 = 1$ lx·s.

9.2.2 Camera OECF

This presentation gives results in a table listing the camera type, the input log luminances of all the test chart patches and the corresponding digital output levels. If the camera system is a multi-spectral system, the digital output levels for all spectral bands shall be listed. The exposure time and camera lens focal length and effective *f*-number shall also be provided. See Table 2.

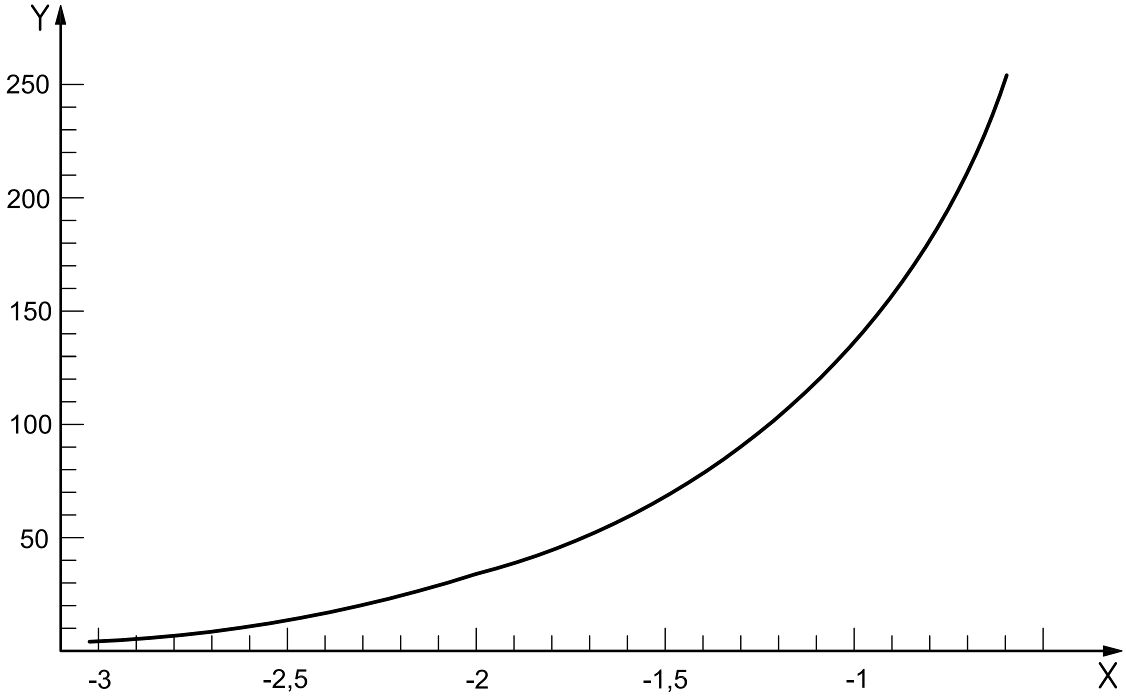
Table 2 — Example of a camera OECF table for an electronic still-picture camera

log exposure	**Mean output levels**		
	Red	**Green**	**Blue**
− 0,22	13,9	14,7	14,2
0,12	19,2	18,8	17,1
0,39	25,1	22,8	20,2
0,61	32,8	28,3	24,9
0,81	43,5	36,8	32,4
0,97	55,1	46,5	41,3
1,12	68,7	58,5	52,4
1,25	82,7	71,3	64,2
1,37	99,0	86,3	78,3
1,48	115,6	102,1	93,2
1,59	133,8	119,6	109,8
1,68	149,6	135,0	124,5
Colour capture (single chip RGB colour filter array camera). Exposure time 1/30 s, 50 mm, lens set at *f*/2,8. Log luminance values calculated from chart density measurements. Daylight illumination, daylight white balance. Tiffen heat mirror IR-blocking filter. Log luminance: $\log_{10}(L/L_0)$, where $L_0 = 1$ cd/m^2.			

9.3 Graphical presentation

9.3.1 Focal plane (method A) and alternative focal plane (method B) OECFs

This presentation gives results in a plot of the digital output level, or $\log_2$ of the digital output level, versus the input log exposure. If the camera system is a multi-spectral system, the digital output levels for all spectral bands shall be plotted. The exposure time shall be provided for intensity scale functions and the focal plane illuminance shall be provided for time scale functions. See Figure 1.



Monochrome capture, time scale exposure series, focal plane illuminance (tungsten) 0,286 lx.

Wratten 301 IR-blocking filter, log exposure: $\log_{10}(H/H_0)$, where $H_0 = 1$ lx·s.

Key

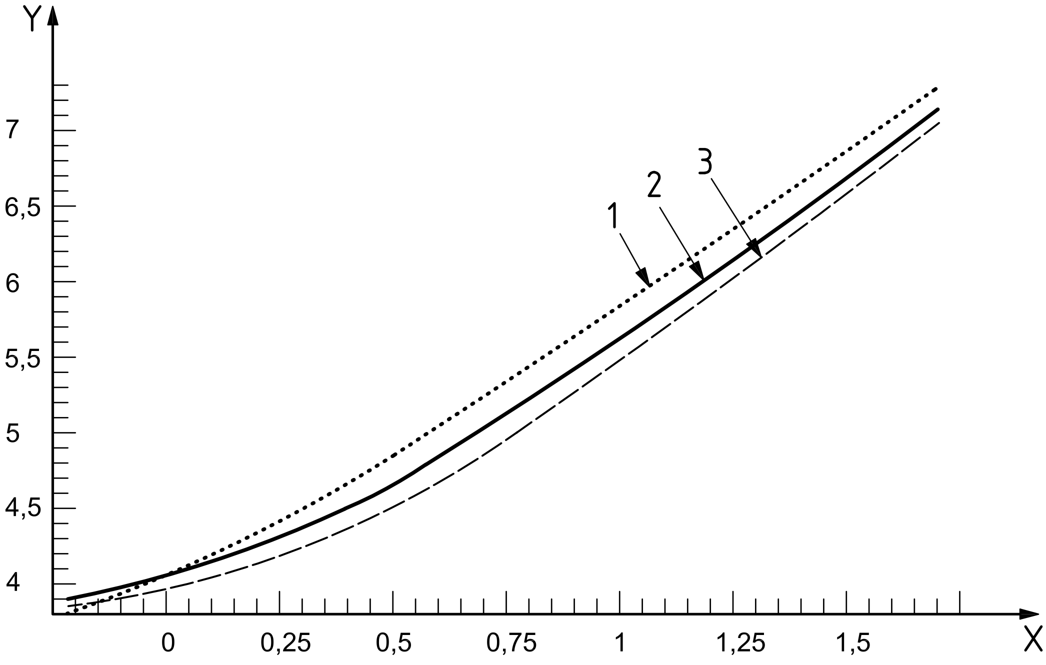
X log exposure

Y output level

Figure 1 — Sample focal plane OECF curve for an electronic still-picture camera

9.3.2 Camera OECF

This presentation gives results in a plot of the digital output level, or $\log_2$ of the digital output level, versus the input log luminances of all the test chart patches. If the camera system is a multi-spectral system, the digital output levels for all spectral bands shall be plotted. The exposure time and camera lens effective *f*-number shall also be provided. See Figure 2.



Colour capture (single chip RGB colour filter array camera), exposure time 1/30 s, 50 mm, lens set at *f*/2,8.

Daylight illumination, daylight white balance.

Tiffen heat mirror IR-blocking filter.

log luminance: $\log_{10}(L/L_0)$, where $L_0 = 1$ cd/m^2.

Key

X log luminance
Y output bits
1 red channel (dotted curve)
2 green channel (solid curve)
3 blue channel (dashed curve)

Figure 2 — Sample camera OECF curves for an electronic still-picture camera

Annex A
(normative)

ISO 14524 camera OECF test chart

A.1 ISO 14524 camera OECF test chart specifications

ISO 14524 camera OECF test charts shall consist of a diffuse emissive surface (reflective or transmissive) with a minimum of 12 neutral (grey-scale) patches stepped in visual density increments which are equal with respect to the cube root of the luminance (± 0,05 density units or ± 12 %). The visual density of the chart background, D_b, shall be set as shown in Equation (A.1):

$$D_\mathrm{b} = 0{,}74\left(\frac{D_\mathrm{d} - D_\mathrm{l}}{2{,}2}\right) + D_\mathrm{l} \tag{A.1}$$

where

D_d is the visual density of the darkest patch;

D_l is the visual density of the lightest patch.

The visual densities shall be determined in accordance with ISO 5-1, ISO 5-2, ISO 5-3 and ISO 5-4 (transmission densities shall be measured using diffuse transmission geometry in accordance with ISO 5). The spectral densities of all areas of the chart, measured in 10 nm or smaller wavelength increments, shall be within 0,10 density units of the mean spectral density between the wavelengths of 420 nm and 680 nm. The grey-scale patches on the chart shall be square, with the sides of each patch of equal length. In the case of 12 patches, the side length shall be $\sqrt{2}/9$ times the chart height (chart short dimension). The patches shall be circularly arranged about the camera optical axis, with a circle passing through the approximate centre of the squares having a radius equal to one-third of the chart height. Framing marks may be provided on the chart for camera aspect ratios ranging from 1:1 to 16:9. A schematic diagram of an ISO 14524 camera OECF test chart with 12 grey-scale patches is provided in Figure A.1. 16 and 20 grey-scale patch schematic diagrams are provided in Figures A.2 and A.3.

Equal cube root increments are specified for the camera OECF test chart because of perceptual considerations and because, due to the effects of flare, equal cube root increments in a scene tend to approach equal log exposure steps at the focal plane. The other specifications are intended to result in the chart simulating an average scene luminance distribution, so that the image formation effects included in the camera OECFs will be representative of those obtained when photographing an average scene. Clause A.2 describes how such charts can be constructed.

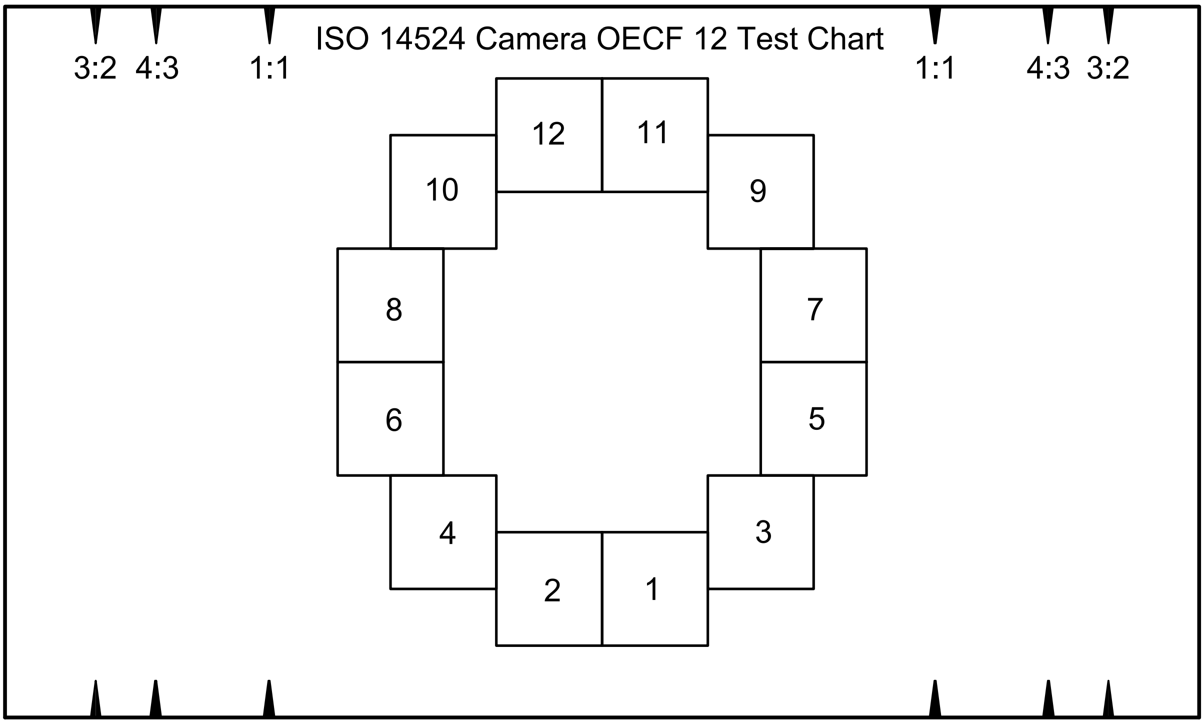


Figure A.1 — 12-patch ISO 14524 camera OECF test chart schematic diagram

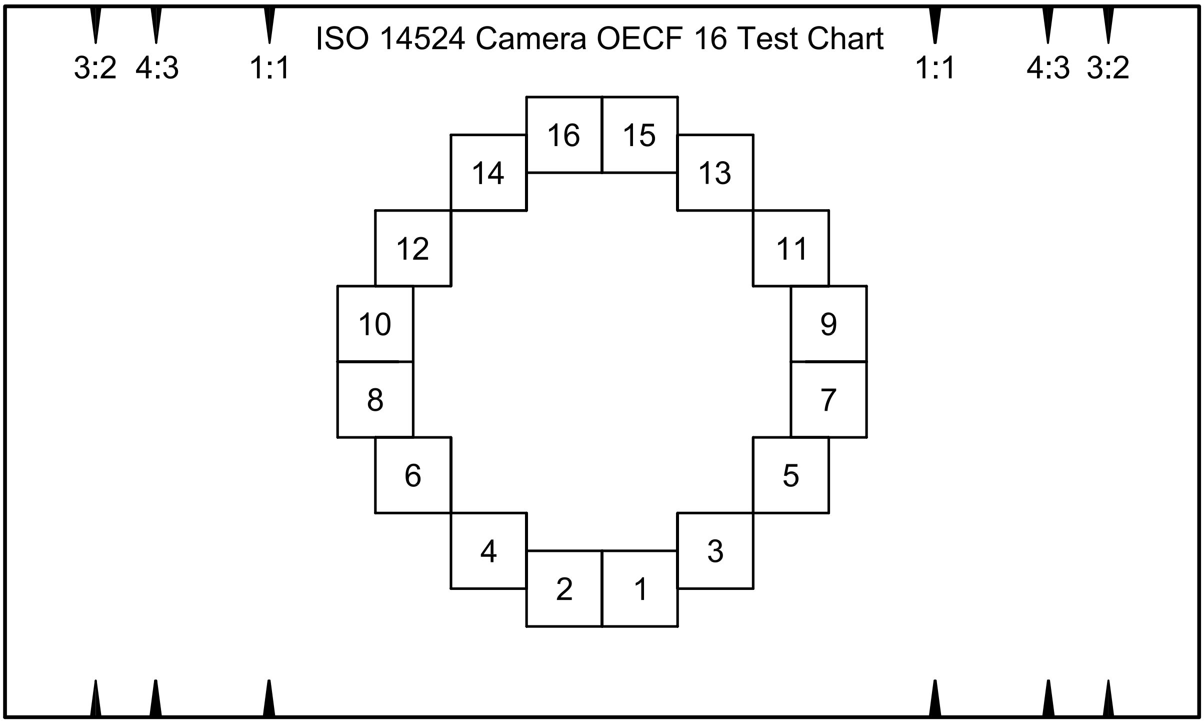


Figure A.2 — 16-patch ISO 14524 camera OECF test chart schematic diagram

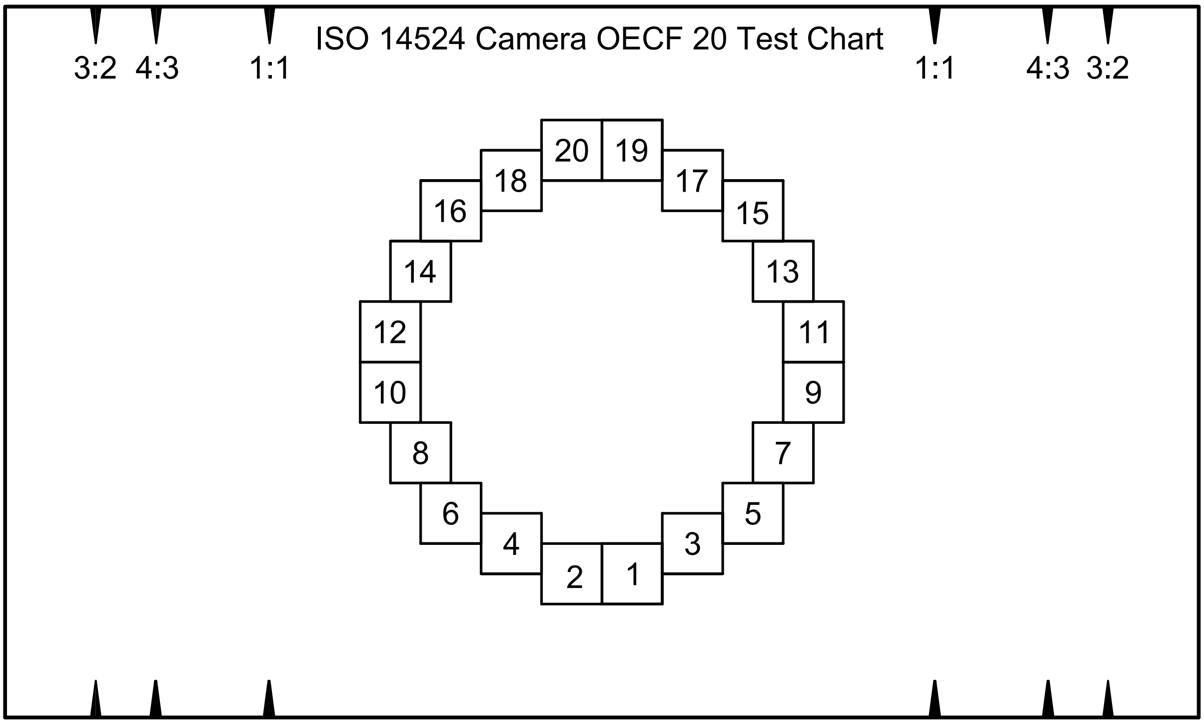


Figure A.3 — 20-patch ISO 14524 camera OECF test chart schematic diagram

A.2 ISO 14524 camera OECF test chart construction

The first step in constructing a camera OECF test chart is to determine the minimum and maximum density capabilities of the material to be used for the chart (D_{min} and D_{max}). From these values, the maximum chart luminance ratio (ΔY_{max}) can be calculated using Equation (A.2):

$$\Delta Y_{\mathrm{max}} = 10^{\left(D_{\mathrm{max}} - D_{\mathrm{min}}\right)} \tag{A.2}$$

The desired luminance ratio (ΔY) is then chosen as a value less than or equal to ΔY_{max}.

After choosing ΔY, equal cube root increments ($Y_i^{1/3}$) can be calculated for each of n steps by subtracting one from the cube root of ΔY and dividing by the number of patches minus one ($n - 1$), and subtracting this value from the cube root of the next higher value, as shown in Equation (A.3):

$$Y_i^{1/3} = \left(Y_{i+1}\right)^{1/3} - \frac{\left(\Delta Y\right)^{1/3} - 1}{n-1}, \quad i = n-1, \ldots, 1, \; Y_n = \Delta Y \tag{A.3}$$

The chart densities (D_i) are then calculated from the $Y_i^{1/3}$ values, as shown in Equation (A.4):

$$D_i = \log_{10}\left[\frac{\Delta Y}{\left(Y_i^{1/3}\right)^3}\right] + D_{\mathrm{min}}, \quad i = n, \ldots, 1 \tag{A.4}$$

Table A.1 shows $Y_i^{1/3}$ and density values, D_i, for four chart luminance ranges ($D_{\text{min}} = 0{,}10$).

Table A.1 — $Y_i^{1/3}$ and density values, D_i, for four chart luminance ranges ($D_{\text{min}} = 0{,}10$)

Step	**Chart type/Luminance ratio**							
	low contrast 20:1		**standard reflection**[a] 80:1		**normal contrast** 160:1		**high contrast** 1000:1	
	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i
1	1,00	1,40	1,00	2,00	1,00	2,30	1,00	3,10
2	1,16	1,21	1,30	1,66	1,40	1,86	1,82	2,32
3	1,31	1,05	1,60	1,39	1,81	1,53	2,64	1,84
4	1,47	0,90	1,90	1,17	2,21	1,27	3,45	1,48
5	1,62	0,77	2,20	0,97	2,61	1,05	4,27	1,21
6	1,78	0,65	2,50	0,81	3,01	0,87	5,09	0,98
7	1,94	0,54	2,80	0,66	3,42	0,70	5,91	0,79
8	2,09	0,44	3,11	0,53	3,82	0,56	6,73	0,62
9	2,25	0,35	3,41	0,41	4,22	0,43	7,55	0,47
10	2,40	0,26	3,71	0,30	4,62	0,31	8,36	0,33
11	2,56	0,18	4,01	0,19	5,03	0,20	9,18	0,21
12	2,71	0,10	4,31	0,10	5,43	0,10	10,0	0,10
background	—	0,54	—	0,74	—	0,84	—	1,11

[a] The average scene luminance ratio is 160:1, but few reflection materials are capable of producing this ratio. For this reason, a luminance ratio of 80:1 is used as a standard value for reflection type charts.

Table A.2 shows $Y_i^{1/3}$ and density values, D_i, for four 16-step chart luminance ranges ($D_{\text{min}} = 0,10$).

Table A.2 — $Y_i^{1/3}$ and density values, D_i, for four 16-step chart luminance ranges ($D_{\text{min}} = 0,10$)

Step	**Chart type/Luminance ratio**							
	low contrast 20:1		**standard reflection**[a] 80:1		**normal contrast** 160:1		**high contrast** 1000:1	
	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i
1	1,00	1,40	1,00	2,00	1,00	2,30	1,00	3,10
2	1,11	1,26	1,22	1,74	1,29	1,96	1,60	2,49
3	1,23	1,13	1,44	1,53	1,59	1,70	2,20	2,07
4	1,34	1,02	1,66	1,34	1,88	1,48	2,80	1,76
5	1,46	0,91	1,88	1,18	2,18	1,29	3,40	1,51
6	1,57	0,81	2,10	1,03	2,47	1,12	4,00	1,29
7	1,68	0,72	2,32	0,90	2,76	0,98	4,60	1,11
8	1,80	0,63	2,54	0,79	3,06	0,84	5,20	0,95
9	1,91	0,55	2,76	0,68	3,35	0,72	5,80	0,81
10	2,03	0,48	2,98	0,58	3,65	0,61	6,40	0,68
11	2,14	0,41	3,20	0,48	3,94	0,51	7,00	0,56
12	2,26	0,34	3,42	0,40	4,24	0,42	7,60	0,46
13	2,37	0,28	3,64	0,32	4,53	0,33	8,20	0,36
14	2,48	0,21	3,86	0,24	4,82	0,25	8,80	0,27
15	2,60	0,16	4,08	0,17	5,12	0,17	9,40	0,18
16	2,71	0,10	4,30	0,10	5,41	0,10	10,00	0,10
background	—	0,54	—	0,74	—	0,84	—	1,11

[a] The average scene luminance ratio is 160:1, but few reflection materials are capable of producing this ratio. For this reason, a luminance ratio of 80:1 is used as a standard value for reflection type charts.

Table A.3 shows $Y_i^{1/3}$ and density values, D_i, for four 20-step chart luminance ranges ($D_{\text{min}} = 0{,}10$).

Table A.3 — $Y_i^{1/3}$ and density values, D_i, for four 20-step chart luminance ranges ($D_{\text{min}} = 0{,}10$)

Step	**Chart type/Luminance ratio**							
	low contrast 20:1		**standard reflection[a] 80:1**		**normal contrast 160:1**		**high contrast 1000:1**	
	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i	$Y_i^{1/3}$	D_i
1	1,00	1,40	1,00	2,00	1,00	2,30	1,00	3,10
2	1,09	1,29	1,17	1,79	1,23	2,03	1,47	2,59
3	1,18	1,18	1,35	1,61	1,46	1,80	1,95	2,23
4	1,27	1,09	1,52	1,45	1,70	1,61	2,42	1,95
5	1,36	1,00	1,69	1,31	1,93	1,44	2,89	1,72
6	1,45	0,92	1,87	1,19	2,16	1,30	3,37	1,52
7	1,54	0,84	2,04	1,07	2,39	1,16	3,84	1,35
8	1,63	0,76	2,22	0,96	2,63	1,04	4,32	1,19
9	1,72	0,69	2,39	0,87	2,86	0,93	4,79	1,06
10	1,81	0,63	2,56	0,77	3,09	0,83	5,26	0,94
11	1,90	0,56	2,74	0,69	3,32	0,74	5,74	0,82
12	1,99	0,50	2,91	0,61	3,55	0,65	6,21	0,72
13	2,08	0,44	3,08	0,53	3,79	0,57	6,68	0,62
14	2,17	0,39	3,26	0,46	4,02	0,49	7,16	0,54
15	2,26	0,34	3,43	0,39	4,25	0,41	7,63	0,45
16	2,35	0,29	3,60	0,33	4,48	0,35	8,11	0,37
17	2,44	0,24	3,78	0,27	4,72	0,28	8,58	0,30
18	2,53	0,19	3,95	0,21	4,95	0,22	9,05	0,23
19	2,62	0,14	4,13	0,15	5,18	0,16	9,53	0,16
20	2,71	0,10	4,30	0,10	5,41	0,10	10,00	0,10
background	—	0,54	—	0,74	—	0,84	—	1,11

[a] The average scene luminance ratio is 160:1, but few reflection materials are capable of producing this ratio. For this reason, a luminance ratio of 80:1 is used as a standard value for reflection type charts.

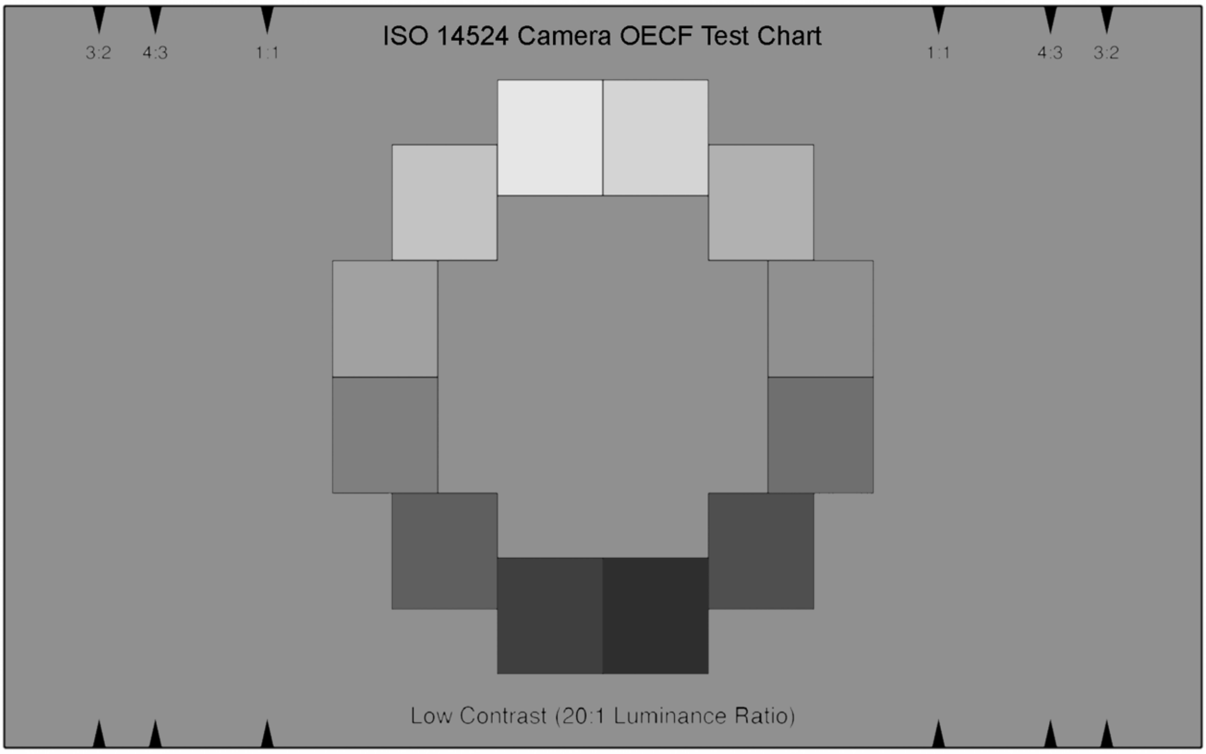
Figure A.4 illustrates a low contrast (20:1) camera OECF test chart with the densities as specified in Table A.1. The 20:1 luminance ratio was chosen for this illustration because of the limited density range capability of the printed output form. A digital file of this test chart is available for output on low noise, spectrally neutral printers. If this file is used for the production of test charts, the digital levels shall be adjusted to produce the appropriate densities. If the printer electro-optical conversion function is known, this can be accomplished using several commercially available software packages.

NOTE The allowable tolerance provides some flexibility in the patch densities a chart may contain.

If test charts are produced by this method, the spectral reflectance/transmittance and noise characteristics of the printer output shall be verified to ensure that the chart produced is spectrally neutral and that the noise level of the printer is sufficiently low so that the patch luminances are effectively constant. Generally, if any printer noise is visible on a chart, the printer used to produce the chart is not acceptable for this purpose.

Printer noise characteristics become even more important if noise measurements, such as are required for the determination of noise speed as described in ISO 12232, are to be obtained from images of the chart. The noise characteristics of a particular chart may be evaluated by comparing the noise present in images of the chart to the noise resulting from focal plane exposures. If consistently more noise is present in the chart images, the source is most likely the chart.

Test charts may also be produced using fine-grain silver halide materials exposed in a manner similar to that described for the focal plane OECF exposures. Pieces of processed film and paper with the required densities are produced in this fashion, and then cut to the appropriate shapes and pieced together to make either a chart, or a master negative which can be used to produce many charts.



NOTE This figure is for illustrative purposes. Prints of this figure (such as paper copies supplied by ISO) will not necessarily meet the requirements of this International Standard.

Figure A.4 — Illustration of a low contrast (20:1) ISO 14524 camera OECF test chart

Annex B
(informative)

Relevance of the ISO 7589 spectral distribution index

Sensitometric tests of the type used for OECF determination measure the response of an image capture system to exposing radiation. The spectral power distribution (SPD) of this radiation is one of the factors that determines the response measured. If sources with different SPDs are used, it is possible that different responses will be measured for the same system, even though the overall amounts of illumination used for the test remain the same. This is because the relationship between the SPD of the exposing radiation and the spectral sensitivity of the system may change.

The best way to eliminate this effect is to use a source which has a specific, desired spectral power distribution. Unfortunately, this is not always practical. The SPD of a real source will change over time. It may also be difficult to duplicate the SPD of a particular desired source, such as daylight, in controlled laboratory conditions. It is therefore necessary to develop a method for determining whether the SPD of a particular source is close enough to the SPD of the desired source so that the measurement results will not be affected. This determination requires knowledge of the spectral sensitivity of the image capture system. The importance of variations in the source SPD depends on the sensitivity of the capture system to these variations.

Historically, two types of image capture systems have been important enough to warrant the development of methods for determining source conformance to an ideal. These systems are the human eye and colour (silver halide) photography. Visual source conformance can be determined for some sources using the method described in CIE 51.2-1999. Photographic source conformance can be determined using the spectral distribution index (SDI) as described in ISO 7589. These methods have similarities and differences. Both methods take advantage of the fact that colour image information is reduced to three channels (a luminance channel and two chrominance channels for the eye, and the red, green and blue channels for photography). The difference between the methods is in how the significance of changes in the SPD is predicted.

The spectral sensitivity of the eye may vary slightly from person to person and depends on the state of adaptation. Nevertheless, average spectral sensitivities are well defined for particular states of adaptation, and appearance models such as CIE L*a*b* are widely used. It is possible to use these models to predict changes in appearance due to changes in the source SPD. Such changes are called metameric effects. CIE 51.2-1999 provides relative spectral reflectance values for a number of hypothetical samples called virtual metamers. Light source conformance is determined by using the CIE L*a*b* appearance model to calculate the predicted difference in the appearance of the virtual metamers under the measured source SPD as compared to the hypothetical desired source SPD. The virtual metamers are chosen to be particularly sensitive to metameric effects. Source conformance is described by averaging the predicted appearance differences and classifying the source accordingly.

The SDI criterion described in ISO 7589 is analogous but somewhat simpler and less precise. It is possible to assume one set of spectral sensitivities for the eye because the eye can adapt, but the exact spectral sensitivities of different photographic systems vary and these sensitivities are fixed for each system. Precise calculations based on average photographic spectral sensitivities will contain errors resulting from the differences between the average sensitivities and the actual sensitivities of the system tested. Photographic source classification can therefore be either more or less precise than visual source classification. If the actual spectral sensitivities of the system being tested are known, it is possible to determine the exact effect of the source SPD — photographic systems do not have observer and adaptation variability. On the other hand, if the actual spectral sensitivities are not known, or if the goal is to classify a source for general use, it becomes impossible to predict exact effects.

The SDI criterion is a method for summing the differences between the SPD of the desired source and the SPD of the actual source. These errors are summed over four bands:

- from 400 nm to 700 nm,
- from 400 nm to 500 nm,

- from 500 nm to 600 nm, and
- from 600 nm to 700 nm.

A source is deemed to be in conformance if the sums of the errors are not larger than a designated value for each band. This approach results in a conformance criterion which is more general, but less precise, than the method described in CIE 51.2-1999. The SDI criterion is not completely general, however, because of the bands chosen. If an image capture system has appreciable sensitivity outside of the SDI bands, or is not based on red, green and blue channel image capture, the SDI criterion may not be appropriate for determining source conformance.

With silver halide photography, the SDI criterion has proven adequate for many years. It should also be adequate for electronic cameras that capture red, green and blue channel information. The advantage of the generality of the approach used is that it is suited to a variety of imaging systems. However, electronic cameras may be built that are not based on red, green and blue channel capture. For example, if an electronic camera is constructed to duplicate the spectral sensitivities of the human visual system under the state of adaptation assumed by the CIE L*a*b* appearance model, the method described in CIE 51.2-1999 would be more appropriate for determining source conformance. The rating obtained using this method, however, would not correlate directly with the SDI rating of the source for use with cameras that capture red, green and blue channels.

Annex C
(informative)

Reporting of the camera OECF in relative reflectance units

Some users of ISO 14524 camera OECF charts may prefer to report the results of measurements in relative reflectance units, e.g. digital output level as a function of chart relative reflectance. This type of reporting is not formally supported by this International Standard because the actual input to the camera is luminance, and the use of relative units can lead to confusion and misinterpretation of results. However, recommendations for relative reflectance reporting are provided for information purposes only in this annex.

The most straightforward way to convert chart luminances to relative reflectances is to take the base ten antilogs of the negatives of the chart densities. Reflectances calculated in this fashion are relative to a perfectly diffuse reflecting surface. This method can also be applied to calculate effective values for the “reflectances” of transmission charts, even though the chart luminances are not produced by reflection. In this annex, reflectances calculated in this fashion will be referred to as chart reflectances.

When ISO 14524 camera OECF test charts are used to simulate real scenes, a more appropriate way to convert chart luminances to relative reflectances is to make them relative to a background reflectance of 0,18. The background density calculated using Equation (A.1) is an attempt to produce a background luminance which is a midtone relative to the patch luminances. In real scenes, a diffuse surface with a reflectance of 0,18 is generally considered to be an approximate midtone, and equal to the statistically average arithmetic mean reflectance. In this annex, relative reflectances calculated in this fashion will be referred to as scene reflectances. Table C.1 lists chart and scene reflectances for the four chart luminance ranges described in Table A.1. Note that the chart and scene reflectances are equal for the standard reflection chart, and that the patch 12 scene reflectance is 1,0 for the normal contrast chart.

Table C.1 — Chart and scene “reflectance” values for four chart luminance ranges ($D_{\text{min}} = 0{,}10$)

Step	Chart type/Luminance ratio							
	low contrast 20:1		**standard reflection** 80:1		**normal contrast** 160:1		**high contrast** 1000:1	
	chart	scene	chart	scene	chart	scene	chart	scene
1	0,040	0,025	0,010	0,010	0,005 0	0,006 3	0,000 8	0,001 8
2	0,062	0,038	0,022	0,022	0,014	0,017	0,004 8	0,011
3	0,089	0,056	0,041	0,041	0,030	0,037	0,014	0,034
4	0,13	0,079	0,068	0,068	0,054	0,068	0,033	0,077
5	0,17	0,11	0,11	0,11	0,089	0,11	0,062	0,14
6	0,22	0,14	0,15	0,15	0,13	0,17	0,10	0,24
7	0,29	0,18	0,22	0,22	0,20	0,25	0,16	0,38
8	0,36	0,23	0,30	0,30	0,28	0,35	0,24	0,56
9	0,45	0,28	0,39	0,39	0,37	0,47	0,34	0,79
10	0,55	0,34	0,50	0,50	0,49	0,62	0,47	1,08
11	0,66	0,41	0,65	0,65	0,63	0,79	0,62	1,43
12	0,79	0,50	0,79	0,79	0,79	1,00	0,79	1,84
background	0,29	0,18	0,18	0,18	0,14	0,18	0,078	0,18

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Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/
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