Standard of the Camera & Imaging Products Association

CIPA DC-004-Translation- 2004

Sensitivity of digital cameras

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In the event of any doubts arising as the contents, the original Standard is to be the final authority.

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Sensitivity of digital cameras

1． Scope The CIPA Standard DCX004 (2004) (hereinafter called "this standard") is applicable to consumer digital still cameras.

2． Framework of this standard

This document comprises three parts as follows:

Part 1：Measurement of Standard Output Sensitivity of digital cameras

Part 2：Recommended Exposure Index of digital cameras

Part 3：Specification Items for Sensitivity of digital cameras

3． Overview

'Standard Output Sensitivity' is a physical measurand defined by light responsiveness of cameras (imaging systems). **'Recommended Exposure Index'** is a recommended index for exposure based on the image quality sensory evaluation by camera vendors. Therefore, these two factors have conceptual differences, however both serve as similar exposure control functions when using a camera, and they are used as indexes to describe a 'practical sensitivity' indicating the necessary amount of light for a camera (imaging system).

These two should be used separately in accordance with the purpose just as both 'ISO speed' and 'Exposure Index' (the former was established based on the light sensitivity of film, and the latter is based on the image quality sensory evaluation of film vendors) have been used depending on the purpose of silver halide cameras. .

Thus, this standard defines both of these as sensitivity of a digital camera. At the same time, comprehensive specification terms for catalogues are stipulated.

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Part 1
Measurement method of Standard Output Sensitivity of digital cameras

1. Scope
This standard is applicable to consumer digital still cameras.

2. Definition of Standard Output Sensitivity
2.1 Conceptual specification
Standard Output Sensitivity (SOS) is a numerical notation that is converted by a prescribed method from the input exposure necessary to obtain specified digital output values for taking still images under specified conditions.

2.2 Numerical specification
Standard Output Sensitivity is the exposure index corresponding to the necessary exposure for obtaining the standard level of digital signal output mentioned in the conditional specification below by using the spectral distribution light defined by the conditions described below.
That is the dimensionless value S obtained by the following equation where said exposure is Hm in the unit ‘lx・s’:

$$\mathbf{S = \frac{10}{Hm}}$$

2.3 Conditional specification
(1) Spectral distribution of measuring light
Two types of measuring lights are specified: **Daylight,** when daylight is assumed, and **Tungsten,** when a studio tungsten lamp is assumed. The measurement of **Daylight** is mandatory.
When measured values of **Daylight** are listed, the description of the measuring light may be omitted, and also the term ‘daylight’ may be included. In the case of **Tungsten**, the term ‘tungsten’ shall appear in the list of the measuring values. (Mount the lens on the camera when measuring, unless otherwise stated.)

- **Daylight:** Use **photographic daylight relative power D55** (note)
- **Tungsten:** Use **studio tungsten relative power** (note)

When measuring Standard Output Sensitivity without a taking lens, on a camera with interchangeable lenses, use:

- **Daylight: ISO sensitometric daylight illuminant** (note)
- **Tungsten: ISO sensitometric studio tungsten illuminant** (note)

Note: These are all in line with **ISO7589 (Table 1 or 2).** See **Annex 1 (Normative)** for details.

(2) Target signal for evaluation

Target signal for evaluation is one of the following signals obtainable from the typical playback system (usually the bundled software), which is designated by the camera manufacturer concerning playback on personal computers.

・Digital grayscale (monochrome) signal（for monochrome cameras）

・Luminance signal **(Y)** calculated by the equation below using digital RGB signals (for color cameras)

$$Y = MAX \times \gamma\{ 0.2126\,\gamma^{-1}\{R/MAX\} + 0.7152\,\gamma^{-1}\{G/MAX\} + 0.0722\,\gamma^{-1}\{B/MAX\} \}$$

MAX is the normalization coefficient（＝maximum digital output level: 255 for 8-bit system）

$\gamma\{\ \}$, $\gamma^{-1}\{\ \}$ denote **sRGB** gamma characteristics and the inverse transformation (linearization) characteristics defined by **IEC61966-2-1.**

(3) Standard Level

The standard level of digital output to obtain **Hm** is

MAX x 0.461

where MAX is the maximum digital output level.

Fractions are dropped. (118 for 8-bit type)

3. Measurement Conditions

3.1 General conditions

(1) Measurement shall be conducted where there is no outside light that may affect the measured values, preferably, in a darkroom.

(2) Measurement shall start after all the tested materials and testing equipment are left in the testing environment until they are fully stable.

3.2 Environmental conditions

(3) Measurement shall be conducted while maintaining **the surrounding temperature at 23°C±2°C** and **relative humidity at 50%±20%**.

3.3 Lighting conditions

(4) Illuminance

Illuminance of **2000 (lx)** on the chart face is set as a standard illuminance. (In the case of transparent chart, the luminance at a clear point is **637 (cd/m^2)**). However, illuminance values can be set discretionarily unless there is some doubt. [note]

Note: The illuminance stated above is defined under the condition that there is no intervening object. If, for example, ND filter is used for measurement, illuminance shall be treated as decreased in response to it. In addition, measuring illuminance does not normally affect Standard Output Sensitivity under a fixed state of sensitivity (when automatic sensitivity adjustment function does not work).

(5) Unevennes of chart luminance

Dispersion of chart luminance shall be 10% or less.

3.4 Camera settings

(6) White balance adjustment

White balance of a camera needs to be adjusted appropriately to the measuring light source. See **Annex 2 (normative)** for specific provisions.

(7) Sensitivity settings

The automatic sensitivity adjustment function of a camera, if there is one, shall be deactivated. The sensitivity adjustment of a camera shall be fixed on one sensitivity point, being a subject of measurement.

Therefore, as a rule, a camera cannot be used for measurement if its automatic sensitivity adjustment function cannot be deactivated. However, when it is observed that a sensitivity adjustment is maintained to be a fixed representative condition during the time of measurement, Standard Output Sensitivity measurement may be conducted as an exception. (note)

Meanwhile, measuring illuminance in such cases is the standard illuminance described above, unless otherwise specifically stated.

Note: See **Annex 3 (Informative)** for specific examples.

(8) Exposure adjustment

Method of exposure adjustment itself is discretionary, however, it is necessary to obtain exposure adjustment values (aperture value and exposure time) used in the mesurement.(note) For this reason, as well as for ease in achieving repeatability of measurement, **a manual exposure adjustment** on cameras is recommended.

The standard exposure time is **more than 1/500 s** but **less than 1/30 s**. If it is out of this range, the condition (exposure time) shall be mentioned.

Note**:** For example, displayed exposure values on a camera or exposure data recorded in the image file as enclosed data can be used. However, it must be noted in this case that errors in the control or notation of a camera are to be directly included as errors of the sensitivity values. See **Annex 3 (Informative)** on this point.

(9) Other automatic adjustment functions

Various other automatic adjustment functions on cameras such as automatic focusing or anti-shake function shall also be deactivated, if it is possible, to measure the sensitivity. However, the deactivation is discretionary when there are no doubts about the measured values.

4. Test Chart

A chart used for measurement shall have a colorless defusing surface with at least one uniform usable part (chip) as a measuring area of illuminance or signal level (which is the area used for the acquisition of measured values; hereinafter called the 'remarkable part').

Said remarkable part shall be included in the area of which **the shading amount (input luminance converted) of the camera being tested is within less than 10% from the center of an imaging area**. Moreover, it is necessary to remove any objects that may cause flare or ghost in all other photographic areas other than the measuring area. From that perspective, it is desirable to cover all the photographic area of the camera being tested as one whole chart.

Note: It is convenient to use a chart with several chips of different reflectance. Annex 3 (Informative) shows an example of measurement using a Grayscale Chart.

5. Method of Measurement (note 1)

(1) Take an image of a chart under the designated light with the camera being tested.

(2) Obtain exposure values, i.e. **the effective aperture value F** (dimensionless quantity) and **exposure time T** (s), of when the digital output value of the remarkable part of the chart equals to the standard level (see **2.3-(3)**).(note 2)

(3) Measure **luminance value B** (cd/m^2) at the remarkable part of the chart described above.

(4) Calculate **the focal plane exposure Hm (lx・s)**, which is a measurement criterion, using the following equation.

$$\mathbf{Hm} = \frac{\mathbf{0.65 \times B \times T}}{\mathbf{F^2}}$$

(5) Obtain Standard Output Sensitivity (calculated value) by the following equation using the focal plane exposure Hm from the calculation above.

$$\mathbf{S\,(calc)} = \frac{\mathbf{10}}{\mathbf{Hm}}$$

Note 1: This method of measurement designates the measurement using a taking lens as a standard measurement method. In the case of a camera with interchangeable lenses, the lens used for the measurement shall be specified (priority is given to the lens included in the product package, if there is any). See Explanation for the calculation equation of (4) stated above.

It is possible to measure Standard Output Sensitivity of a camera body which has standard spectral characteristics without a lens, by giving imaging surface(that is focal plane) illuminance E (lx) in an appropriate way and using the value Hm= E・T in the equation (4).

Note 2: Various devices are used in many practical cases in order to the obtain exposure values described in (2). See **Annex 3 (Informative)** for specific measurement methods in such cases.

6. Assigned value

(1) An Assigned value is basically a rounded figure of the calculated value S (calc) according to the conversion table in section 7.

(2) It is expressed as a dimensionless figure without unit. ' **S** ' may be used as a symbol.

［**Examples of Notation**］

Standard Output Sensitivity: S = 100

Standard Output Sensitivity: 400

(3) There are some cases where the sensitivity varies depending on the value of F due to structural factors of an image pickup device, etc. If this change in sensitivity affects the assigned value mentioned above, the measurement conditions (F-value) shall be mentioned.

Note**:** Product level specifications in catalogues, etc. are stipulated in **Part 3 'Notation of Sensitivity of digital cameras**' of this standard.

7. Conversion Table of assigned values from measured values (calculated values)

Calculated value (calc)		Assigned value	Calculated value (calc)		Assigned value	Calculated value (calc)		Assigned value
more than	less than		more than	less than		more than	less than	
8.909	11.22	10	89.09	112.2	100	890.9	1122	1000
11.22	14.14	12	112.2	141.4	125	1122	1414	1250
14.14	17.82	16	141.4	178.2	160	1414	1782	1600
17.82	22.45	20	178.2	224.5	200	1782	2245	2000
22.45	28.28	25	224.5	282.8	250	2245	2828	2500
28.28	35.64	32	282.8	356.4	320	2828	3564	3200
35.64	44.90	40	356.4	449.0	400	3564	4490	4000
44.90	56.57	50	449.0	565.7	500	4490	5657	5000
56.57	71.27	64	565.7	712.7	640	5657	7127	6400
71.27	89.09	80	712.7	890.9	800	7127	8909	8000

Note : The figures in the conversion table above shall basically be rounded at 1/3 unit ($2^{1/3}$ times) steps. This standard selects a linear value as a reference, namely, 'arithmetic notation'. Another expression, 'logarithmic notation', may also be obtained in the same manner. See **Annex 4 (Informative)** for details of comprehensive conversion rules.

Part 2: Recommended Exposure Index of digital cameras

1. Scope

This standard is applicable to consumer digital still cameras.

2. Definition of Recommended Exposure Index

2.1 Conceptual specification

Recommended Exposure Index is an exposure index corresponding to the average exposure in a focal plane recommended by camera (imaging system) vendors (manufacturers etc.) for the purpose of reference to the setting an exposure index (film ISO speed value) when using a separate exposure meter or accessory strobe etc..

That is a dimensionless value calculated by the equation

$$\mathbf{REI = 10 / Em}$$

where Em is said recommended average exposure in the focal plane in the unit ‘lx・s'. (note 1)

Note 1: Theoretical value is designated as a **calculated value REI (calc).** See section **4**. ‘Assigned value’ for the values used for notation.

2.2 Conditional specification

2.2.1 Illumination lighting

Recommended Exposure Index may vary depending on spectral luminance of lights. Two types of lights are specified in this standard : **Daylight is** when daylight is assumed. **Tungsten** is when a studio tungsten lamp is assumed.

The intended light is **Daylight** unless otherwise noted, and also the term ‘daylight’ may be noted. In the case of **Tungsten**, the term ‘Tungsten’ shall be noted to indicate Recommended Exposure Index.

- Daylight: Use **photographic daylight relative power D55** note
- Tungsten: Use **studio tungsten relative power** note

Note: These are in line with **ISO 7589 (Table 1 or 2).** See **Annex 1 (Normative)** for details.

2.2.2 Other conditions

If Recommended Exposure Index changes depending on environmental conditions, or mode settings of the camera, the conditions shall be clearly mentioned as such**.** If no conditions are mentioned, general usage is assumed.

3. Relation to Automatic Exposure systems

When the camera in question is equipped with a **traditional (i.e. simple)** automatic-exposure function, the average exposure in the focal plane given by the automatic-exposure function to a uniform photographic subject must naturally be equal to the above-mentioned Em value recommended by the vendor of the camera.

In this case, the following equation is satisfied:

$$\mathbf{AV + TV = BV + \log_2(0.32 \times REI)}$$

(Where: $\mathbf{AV = \log_2 F^2}$

$\mathbf{TV = - \log_2 T[s]}$

$\mathbf{BV = \log_2 \{ B\ [cd/m^2]/(0.32 \times K \}\}}$[note 1])

Therefore, the value of REI can be assumed (indirectly measured) from this relationship by measuring the performance of the automatic-exposure function.[note 2]

On the contrary, a specific relationship with automatic-exposure function does not exist in a camera with **advanced** automatic functions; for example, when the controller varies the level of exposure in the focal plane in accordance with the patterns or absolute luminance value of a photographic subject. Thus, in this case, there is no way to measure REI directly or indirectly.

Note 1: The application of $BV = \log_2 \{0.292 \times B\ [cd/m^2]/ k \}$ is accepted. K refers to the metric and k refers to the imperial system of calibration factor. The former is mostly used for specifications of a stand-alone exposure meter and the latter for a light box for adjustment of the automatic-exposure controller. Standard settings in recent years seem to adopt K=14 or k=1.3 although it is left to the discretion of each manufacturer. When BV values are obtained directly from an exposure meter to measure luminance of a photographic subject instead of using a luminance meter, the calibration factor of the exposure meter results in being assumed.

Note 2: This standard stipulates only the Recommended Exposure Index (recommended average exposure in focal plane), and does not stipulate the performance of the automatic-exposure function.

4. Assigned value

(1) An assigned value is basically a rounded figure of the calculated value REI (calc) according to the conversion table in section 5.

(2) It is expressed as a dimensionless figure without unit. ‘**REI**’ may be used as a symbol.

［**Examples of Notation**］

Recommended Exposure Index: REI = 100

Recommended Exposure Index: 400

Note: Product level specifications in catalogues, etc. are stipulated in **Part 3 ‘Notation of Sensitivity of digital cameras**’ of this standard.

5. Conversion Table of assigned values from calculated values

Calculated value (calc)		Assigned value	Calculated value (calc)		Assigned value	Calculated value (calc)		Assigned value
more than	less than		more than	less than		more than	less than	
8.909	11.22	10	89.09	112.2	100	890.9	1122	1000
11.22	14.14	12	112.2	141.4	125	1122	1414	1250
14.14	17.82	16	141.4	178.2	160	1414	1782	1600
17.82	22.45	20	178.2	224.5	200	1782	2245	2000
22.45	28.28	25	224.5	282.8	250	2245	2828	2500
28.28	35.64	32	282.8	356.4	320	2828	3564	3200
35.64	44.90	40	356.4	449.0	400	3564	4490	4000
44.90	56.57	50	449.0	565.7	500	4490	5657	5000
56.57	71.27	64	565.7	712.7	640	5657	7127	6400
71.27	89.09	80	712.7	890.9	800	7127	8909	8000

Note: The figures in the conversion table above shall basically be rounded at 1/3 unit ($2^{1/3}$ times) steps. This standard selects a linear value as a reference, namely, ‘arithmetic notation’. Another expression, ‘logarithmic notation’, may also be obtained in the same manner. See **Annex 4 (Informative)** for details of comprehensive conversion rules.

Part 3: Notation of Sensitivity of digital cameras

1. Scope

This standard is applicable to product specifications for general consumers, including instruction booklets and catalogues, which document the sensitivity of consumer digital still cameras.

2. Notation of Sensitivity

2.1 Notational terms

(1) Characteristics to be specified as '**Sensitivity**' are the assigned values of **Standard Output Sensitivity (symbol: SOS),** and/or **Recommended Exposure Index (symbol: REI).** The use of both or either shall be acceptable. When both are listed, Standard Output Sensitivity shall come first, followed by Recommended Exposure Index. It is also acceptable to use the terms 'Standard Output Sensitivity' and/or 'Recommended Exposure Index' as notational terms of each value instead of using the word 'Sensitivity'.

(2) When assigned values are specified as '**Sensitivity**' in catalogues or instruction booklets, either **Standard Output Sensitivity** or **Recommended Exposure Index** shall be listed.

(3) However, the requirement in above (2) is not necessarily adopted in the case that assigned values have already been listed as specifications in other sections of the instruction booklets or catalogues, and also the described assigned values are not listed as specifications, for example:

(a) A description of assigned values in the explanations of sensitivity in other (not specific) sections

(b) The indication of assigned values on the camera body itself pertaining to the operation of the exposure device.

(4) The word 'CIPA' may be used to specify that assigned values are in line with this standard.

(5) When the measurement method complying with this standard is adopted as ISO Standards*, the assigned values of sensitivity measurement may be listed in accordance with the notations specified in Section 3, Examples of Notations, Remarks 1.

* Contents of both Part 1 and Part 2 (Standard Output Sensitivity and Recommended Exposure Index) of this standard shall most likely be incleded in the next revision of the relevant standard, ISO 12232 (scheduled to be issued in 2004; hereinafter called 'Revised ISO 12232 standard').

2.2 Assigned values to be listed

(1) The basic notation of assigned values of characteristics of Standard Output Sensitivity and Recommended Exposure Index follows the calculation method and conversion method described in Part 1-6 and Part 2-4 of this standard respectively.

(2) Assigned values of the specifications to be listed in catalogues shall be selected from the values listed in Part 1-7 and Part 2-5 of this standard.

Note: A list of specific values for information on piece-to piece variations in individual products, targeting advanced users (for example, individual data sheets) falls into an exception of the application of this section.

(3) A case where assigned values are different in the same camera depending on a function mode:

When the value under a particular mode is represented, priority shall be given to the value of the function mode with the highest probability of use such as 'default-setting', and it is desirable to specify the particular function mode along with the value.

When every assigned value of different function modes is listed, each of the corresponding function modes shall be specified.

3. Examples of Notations

(Example 1) Sensitivity/Standard Output Sensitivity: 125
Recommended Exposure Index: 100

(Example 2) Sensitivity: 100 (Standard Output Sensitivity)

(Example 3) Sensitivity: 100 (REI)
(* REI: Recommended Exposure Index)

(Example 4) Sensitivity: 100 (CIPA Standard Output Sensitivity)

(Example 5) <When Standard Output Sensitivity and Recommended Exposure Index of the camera in question have the same values>
Sensitivity: 100 (by CIPA standards)

Remarks 1: When the revised ISO 12232 standard (scheduled to be issued in 2004) is adopted, the following examples may additionally be used.

(Example 6) Sensitivity/Standard Output Sensitivity: ISO 125
Recommended Exposure Index: ISO 100

(Example 7) Sensitivity: ISO 100 (Standard Output Sensitivity)

(Example 8) Sensitivity: ISO 100 (REI)
(* REI: Recommended Exposure Index)

(Example 9) Sensitivity: 100 (ISO Standard Output Sensitivity)

(Example 10) <When Standard Output Sensitivity and Recommended Exposure Index of the camera in question have the same values>
Sensitivity: 100 (ISO Standard Output Sensitivity, ISO Recommended Exposure Index)

Remarks 2: When the symbols SOS and REI are used instead of 'Standard Output Sensitivity' and 'Recommended Exposure Index', it is desirable to state both symbols and spelled-out words as in the examples 3 and 8 (written in the margin, etc.) at least until these symbols have been well disseminated in the market.

Annex 1 (Normative) Spectral distribution of measuring light

1. Objective characteristics

Relative spectral power distribution of **ISO 7589-1984** in the second column (the fourth column when lenses are not used for the measurement) of the tables below **(table 1, table 2)** are designated as objective characteristics.

Note: Standard errors to evaluate whether the light being tested corresponds to the objective characteristics are discussed later in section 2 of this annex; and therefore, the 'objective characteristics' listed here may be considered as reference characteristics. Objective characteristics are the characteristics having zero error variance in section 2.

Similar information pertaining to ISO 7589-1984 with the relevant parts of this standard can be found in JIS K7602-1984 (which was abolished, but is still available).

Table 1 — Relative spectral power distribution, S_λ, of ISO sensitometric daylight illuminant

Wavelength, λ	Photographic daylight[1] relative power,	Relative spectral transmittance of the ISO standard lens	ISO sensitometric daylight illuminant (daylight transmited by lens),	Weighted spectral sensitivities for calculating ISO/SDI of daylight illuminant		
				Blue	Green	Red
nm	D_{55}	$\bar{\tau}(\lambda)$	$S_\lambda = D_{55}\bar{\tau}(\lambda)$	$W_B(\lambda)$	$W_G(\lambda)$	$W_R(\lambda)$
350	28	0,00	0			
360	31	0,07	2	1		
370	34	0,23	8	2		
380	33	0,42	14	5		
390	38	0,60	23	9		
400	61	0,74	45	14		
410	69	0,83	57	17		
420	72	0,88	63	19		
430	68	0,91	62	19		
440	86	0,94	81	17		
450	98	0,95	93	15		
460	100	0,97	97	13		
470	100	0,98	98	9	1	
480	103	0,98	101	5	1	
490	98	0,99	97	2	1	
500	101	0,99	100	1	2	
510	101	1,00	101	1	3	
520	100	1,00	100		5	
530	104	1,00	104		8	
540	102	1,00	102		15	
550	103	1,00	103		24	1
560	100	1,00	100		12	1
570	97	1,00	97		13	1
580	98	1,00	98		10	2
590	91	0,99	90		3	3
600	94	0,99	93		1	5
610	95	0,99	94			7
620	94	0,98	92			9
630	90	0,98	88			14
640	92	0,97	89			21
650	89	0,97	86			26
660	90	0,96	86			18
670	94	0,95	89			4
680	90	0,94	85			1
690	80	0,94	75			

1) Data for D_{55} daylight from CIE Publication No. 15 (E-1.3.1), table 1.1.4.

Table 2 — Relative spectral power distribution, S_λ, of ISO sensitometric studio tungsten illuminant

Wavelength, λ	Studio tungsten relative power	Relative spectral transmittance of the ISO standard lens	ISO sensitometric studio tungsten illuminant (studio tungsten transmitted by lens)	Weighted spectral sensitivities for calculating ISO/SDI of studio tungsten illuminant		
				Blue	Green	Red
nm		$\bar{\tau}(\lambda)$	S_λ	$W_B(\lambda)$	$W_G(\lambda)$	$W_R(\lambda)$
350	1	0,00	0	1		
360	3	0,07	0	2		
370	5	0,23	1	5		
380	8	0,42	3	12		
390	12	0,60	7	22		
400	16	0,74	12	32		
410	20	0,83	17	40		
420	24	0,88	21	44		
430	29	0,91	26	45		
440	34	0,94	32	40		
450	38	0,95	36	36		
460	43	0,97	42	31		
470	48	0,98	47	21	1	
480	53	0,98	52	11	1	
490	59	0,99	58	5	1	
500	64	0,99	63	2	2	
510	70	1,00	70	1	3	
520	76	1,00	76		5	
530	81	1,00	81		8	
540	88	1,00	88		15	
550	94	1,00	94		24	1
560	100	1,00	100		12	1
570	105	1,00	105		13	1
580	111	1,00	111		10	1
590	116	0,99	115		3	2
600	122	0,99	121		1	3
610	127	0,99	126			4
620	132	0,98	129			5
630	138	0,98	135			8
640	143	0,97	139			13
650	148	0,97	144			15
660	153	0,96	147			11
670	157	0,95	149			3
680	162	0,94	152			0
690	167	0,94	157			

2. Criterion of spectral power distribution error for real light source

The requirements are follows: **SDI (Spectral Distribution Index)** is obtained in accordance with **Chapter 5 of ISO 7589,** and it satisfies the error criterion stipulated in **Chapter 6 of ISO 7589**. Specifics are described below in sections **2.1 and 2.2**.

2.1 How to obtain SDI

Relative spectral sensitivity of the evaluated light is expressed as **S(λ)** (where λ is a wavelength).

Using relative spectral transmittance, **τ(λ),** of the **ISO standard lens** in the third column of the above **tables 1 and 2**, and weighted spectral sensitivities, **Wc(λ),** of three colors, namely blue, green and red, which are listed in three columns at the right side of each table **(table 1 for daylight and table 2 for tungsten)**, response **Rc** to each color can be calculated by the equation below.

$$R_C = \int_0^{\infty} W_C(\lambda) \times S(\lambda) \times \tau(\lambda)\, d\lambda$$

(Where C represents one of three colors: B, G or R).

In reality, however, the dispersion value at each **10 nm** of wavelength listed in each table is calculated as the following equation shows:

$$R_C = \sum_{\lambda=350}^{700} W_C(\lambda) \times S(\lambda) \times \tau(\lambda)$$

(When measuring without a taking lens, adopt $\tau(\lambda) = 1$ in the equation above.)

Calculate $\log_{10} Rc$ to two decimal places for each response, and multiply the each difference with the minimum value of these three values by one hundred respectively. The obtained values, which are arranged in the order of Blue, Green, and Red with slash symbols in between, are called the **'Spectral Distribution Index'**.

Note: From the definition above, it is derived that whenever the minimum color index is zero, the other two indexes must be positive whole numbers. The SDI itself is defined above. Thus, the relationship among the three indexes is relative and only the difference among them has any meaning. Therefore, if the same value is added or subtracted, the resulting figures have absolutely the same meaning.

2.2 **Error** criterion

Index value for blue of the measured light shall be **within ±4** of that for green, and the vlue for red **within ±3** of that for green.

Note: An example of a light source satisfying the above error criterion for **daylight illuminants D55** is described in **Annex 5 (Informative)**.

Annex 2 (Normative) White Balance adjustment for cameras

White balance of a camera shall be adjusted adequately to the measured light source. Specific provisions are described below.

(a) No standard is applicable to a camera without a **WB** adjustment function (including monochrome cameras).

Apply one of **(b)**～**(e)** provided below to a camera with a WB adjustment function.

(b) When the light source is daylight and a camera is manually adjustable to a preset WB value of a camera with a setting position described with the term 'daylight' or a similar expression, a measurement can be performed by using this position.

(c) When the light source is tungsten and a camera is manually adjustable to a preset WB value of a camera with a setting position described with the term 'tungsten' or a similar expression, a measurement can be performed by using this position.

(d) When a camera is equipped with an automatic WB function, a measurement can be performed while keeping the function activated. If the adjusted value can be locked once automatically adjusted (WB lock), a measurement shall be performed while keeping it locked.

(e) Even in the following cases:

- When a camera does not fall under any of the provisions listed above (one having a WB adjustment function but no preset value corresponding to the light source).
- When a camera that falls under a provision listed above and its WB error can be made smaller.

a measurement can still be performed while keeping the adjustment in such a way so that the WB error under the measuring light source is kept at a minimum.

Note 1: WB adjustment function shall work prior to the completion of the photographic recording. (In other words, WB adjustment function shall not be used for measurement during the playback.)

Note 2: The degree of **WB error** in (e) can be calculated by the digital RGB values of the playback signal on the remarkable part of the chart as shown in the following equation.

$\{ (R - G)^2 + (B - G)^2 \}^{1/2}$, and the obtained value can be used as evaluation value.

Note 3: For the public disclosure of Standard Output Sensitivity, the following two information items shall be recorded so as to be readily disclosed:

- Information as to 'which method from (**b)**～**(e)** has been used'
- The 'degree of WB error when **(e)** is used'.

However, when the sensitivity is described in catalogues, etc., these items may be omitted.

Annex 3 (Informative)
Recommended measurement method (An example)

1. Equipment for Measurement

・A camera being tested and designated playback software
・A fixing apparatus for the camera: for example, a tripod
・A spot luminance meter
・A chart: Grayscale chart of γ=0.45; for example, IEC1146-1 Test chart No. 1 or ITE Grayscale Chart II (Dai Nippon Printing Co., Ltd.), etc.
・Lighting equipment: lamp(s) or a light box (incandescent lamp type); for example, relative color temperature 3200 K Tungsten lamp (light intensity adjusted by single-phase auto transformer, measured by Color temperature meter)
・Color temperature conversion filter: for example, LB-120 filter of HOYA Corporation
・Personal computer and analyzing software (example: Photoshop™ ver. 5 of Adobe Systems Incorporated may be used)
・ND (neutral density) filters, etc., when necessary

2. Procedures for Measurement

(1) A camera being tested should be set up and fixed in such a position so as to be able to take an image of a chart placed under standard lighting conditions (in the case of daylight, obtain the light with spectral characteristics equivalent to D55 using color temperature conversion filter). The following two points should be noted for this procedure:

・If a camera features a zoom function and the F-value of the lens is designated in a certain zoom position, select that position.
・Adjust the distance to the chart and the zoom in such as way so as to be able to take a full image up to the ▲ marks on four sides of the grayscale chart. (This is not always required.)

(2) Adjust exposure values (aperture and time) in such a way so as to be able to take an image in generally good condition (so that the gray area in the background reaches around 40 to 60% of the digital output). When the camera is equipped with automatic exposure function and the exposure value is known, automatic exposure is accepted.

Also, when a camera has a gain variable function that can be fixed, use it under the fixed condition.

Note 1: Even if a camera has a gain (sensitivity) adjustment function that cannot be fixed, the measured value of sensitivity may be regarded as a representative value of sensitivity when the sensitivity near the reference luminance defined in section 3.3(4) does not change. This is because an adjusted sensitivity condition is assumed to be maintaining a representative fixed state at the time of measurement. (If it is a general camera, the condition above can often be fulfilled under standard lighting conditions.) In addition, the standard lighting should be adopted under the

same conditions with the same values not only for the measurement of sensitivity but also for other specifications (SN, etc.).
In addition to the above, if it is possible to maintain the adjusted sensitivity of a camera at a maximum level by reducing the luminance of the target, this is also assumed to be maintaining a representative fixed state that is different from the condition mentioned above. This enables the obtainment of another representative sensitivity, namely, the 'maximum sensitivity'.

Note 2: It must be noted that errors contained in the control or the reading values are directly involved in the errors of the measured sensitivity when using the exposure value determined by the exposure control function of a camera.
It is possible to reduce such measurement errors. An exposure time (shutter speed), for example, can be experimentally measured by measuring the image blurring by taking an image of a given moving subject. On the other hand, there is no effective way to reduce errors in aperture correction (F-value). Nonetheless, the full-open F-value of the lens is known to be trustworthy, and it is possible to reduce the errors by using such open aperture. (Note 3 below shows an example of measurement using an open aperture.)

Note 3: When the exposure value of a camera with automatic exposure function is not displayed, its exposure value can be obtained by the following method of photography (however, it must be noted this may also induce some errors when ND filter is used). This is possible only when the camera in question possesses a Fixed Gain Mode (one with no auto gain-up function or one whose auto gain-up function can be deactivated).
・When an image is taken, the aperture should be held fully open. In other words, insert ND filter in front of the camera if necessary, and capture the timing when the level of output image is lowered, that is, when the aperture is open and shutter speed is the longest exposure time.

(3) Playback the image that has been taken, and analyze the output level. [Note] The sampling area can be obtained by selecting a middle range of each gradation of grayscale (preferably several hundred pixels or more) and calculate the mean values.
Take a measurement at each step. Select one step higher and one lower than the standard level D (example: 118 / 8 bit) and record the output level DU and DL (DU＞D＞DL) values, then measure the corresponding subject luminance values, BU and BL (luminance at the grayscale area), using a spot luminance meter. (When an ND filter is used for photography, measure its luminance by placing the same ND filter at the front of the luminance meter.)
Note: when a color image is measured, for example when using Photoshop, the level can be measured as follows:
- Convert the target image into grayscale image while designating the color space as sRGB.
- Measure the level by using either the 'information' display function or 'histogram' function.

(4) Calculation of Standard Output Sensitivity

Measured exposure values at two steps are expressed as HU and HL (HU＞HL). Each H (unit lx・s) is obtained from the following equation by photographic subject luminance B (cd/m^2), exposure time T(s), and aperture value F.

$$\mathbf{H} = \frac{\mathbf{0.65 \times B \times T}}{\mathbf{F}^2}$$

Calculate exposure value Hm corresponding to a standard level D by using the following equation.

$$\mathbf{Hm} = \frac{\mathbf{(DU - D) \times HL + (D - DL) \times HU}}{\mathbf{DU - DL}}$$

Note: When either DU or DL is identical to the value of D, H, which directly corresponds to them, becomes the same value of Hm, instead of interpolating. In this case, it is obvious that the rule in this text (5. Measurement Method) does not change. Interpolating method demonstrated above is simply an example of a practical substitution method of measurement, extending the consideration to the case where it is difficult to synchronize the remarkable part of the chart exactly to the value of D.

The interpolating equation mentioned above may contain some errors since it uses a collinear approximation (in the case of typical gamma characteristic of $\gamma=0.45$, maximum of 2%). In order to reduce the error, use interpolating value assuming typical γ instead of using collinear approximation (or even more preferably, one based on the gradation characteristics of the camera being tested). A similar error reduction effect may be obtained in a relatively simple manner by the logarithmic collinear approximation (to bring the results obtained by linear interpolation on a double logarithmic plot back to antilogarithm).

Annex 4 (Informative)
Rules for conversion of assigned values from measured values (calculated values)

The Conversion Table in the main text (Chapter 7 of part 1 and Chapter 5 of pert 2) is compiled based on the following rules. Therefore, an extended application can be considered in accordance with its rule when the new situations that may fall outside of the scope of application of the table.

Notational value is based on 10^N, and is rounded to 1/3 unit ($2^{1/3}$ times) steps (placing the numerical value of 10^N at the logarithmic center of each step). Therefore, a single digit (ten times) is divided logarithmically into about 10. Since $2^{10/3} = 10.08 \neq 10$, only the last step ($S = 8 \times 10^N$) corresponds to a slightly smaller step.

Thus, in each column corresponding to N＝0, 1, 2, 3, the threshold of determining the scope of S (calc) value (the figures listed in the column 'more than') can be obtained by using positive integer M= from 0 to 9 at each step (row) of the table by the equation below.

$$\mathbf{10^{N} \times 2^{(2M-1)/6}}$$

The representative value of each step is the value of the logarithmic mean, but some possess fractions. As far as the numeric sequence used in the notation is concerned, essential and adequate figures are adopted based on the present usage in the realm of photography.

The value of the 'logarithmic expression' corresponding to the obtained sensitivity (arithmetic expression) equals:

$$\mathbf{10 \times N + M + 1}$$

Annex 5 (Informative)
An example of Daylight Simulator equivalent to D55

As far as D55 daylight luminance is concerned, it is found in the calculation that a light source within the error range stipulated in **Annex 1** can be obtained by combining a 3200 K tungsten lamp and a HOYA LB-120 Glass Filter (HOYA Optics Corporation).

Calculated value of SDI is **0/3/1.**

However, the calculation was conducted under the following conditions:

- Spectral distribution characteristics of the tungsten lamp are substituted by blackbody radiation characteristics with the same temperature.
- Data on the filter spectral characteristics are substituted by the typical value listed in the catalogue.

Therefore, the calculation does not guarantee that the error obtained in practice will lie within the error range described above, nor is using the filter mentioned above recommended.

Explanation

This explanation describes the items and the related matters stipulated and included in this standard and its Annexes, and thus it does not constitute a part of this standard.

1. Standard Output Sensitivity

ISO 12232, established in 1998, stipulates ISO Speed of digital cameras. However, it stipulates that the main value of 'ISO noise speed' should not be applied to a camera with lossy compression because the values vary due to the compression process during image recording. Therefore, it had application restrictions on general consumer cameras.

In the meantime, the term "sensitivity" (or ISO speed) of film is an exposure index based on the gradation characteristics. If it is accepted that the sensitivity of digital cameras should be stipulated in a similar manner, the sensitivity can be defined by using exposure values that give the prescribed standard output level. Similarly, the sensitivity of video cameras (including minimum subject luminance and standard sensitivity of professional cameras) is defined to be the standard output level of 50 IRE. ISO 12232 also stipulates 'ISO saturation speed'; which is similar to these, but a problem is that 'values are largely affected by the Knee characteristics even if the actual sensitivities are the same' because it uses the saturation level as the standard level.

Taking the above into consideration, this standard adopts the medium level on the tone curve as the sensitivity standard level. Specifically, Y-value was designated as the reference value for sensitivity measurement in the color space sRGB, which is the target of digital cameras in compliance with the Exif standard. The value of Y corresponds to a typical 18% neutral gray subject obtained by relating the maximum digital output (255 for 8 bit) to a subject reflectance rate of 100% (118 for 8 bit sRGB).

In other words, Standard Output Sensitivity (S) is stipulated as

$S = 10/H_m$ (Where, Hm is the input luminance value to give the standard level of output =118<at 8 bit> : unit lx・s)

(The conversion system itself is the same as that of existing reversal films or the **ISO 12232** standard.)

2. Recommended Exposure Index

It is not uniformly defined what an 'appropriate exposure' is, because it depends heavily on the preference of the individual subjects or photographers. Nevertheless, in light of the importance of the exposure of cameras, attempts have been made to set up a 'standard exposure', which is to help attain maximum rate of success. In many cases, the auto exposure adopted by makers of digital cameras is the embodiment of such 'standard exposure' or 'recommended exposure by manufactures to help attain maximum rate of success'. (However, this is not to say such

recommended exposure itself by the manufacturer is the 'appropriate exposure' for a photographer in practice.) In recent years, various methods have become available to process luminance information, using partial photometry information taken from multiple parts of the subject, including Pattern Photometry or Peak Photometry.
On the other hand, when the aperture or shutter speed is to be obtained by using a reflective stand-alone exposure meter or accessory strobe, the average photometry values are used. Adequate preset value of film sensitivity (exposure index) must be adapted to such equipment during photography, in which case the recommended value preset by the maker (in other words, the value to obtain the 'standard exposure' mentioned above) is the 'Recommended Exposure Index'.
The preset value of the film sensitivity or exposure value corresponds to the exposure on the imaging surface (the inverted number based on an appropriate constant number in practice). Therefore, an indication of Recommended Exposure Index is the same as showing the value of 'average exposure in the focal plane recommended by makers for the average photometry' or 'average exposure in the focal plane obtained as a result of photography by using auto exposure with traditional average photometry'. Moreover, constant number 10 ［lx･s］ of REI = 10/Em, which is used to convert the exposure in the focal plane into the exposure index, has been set the same as the relationship between ISO speed and exposure value in the focal plane stipulated in **section 5.4 Exposure in the focal plane** of **ISO 2721 Cameras–Automatic controls of exposure**.

3. Supplement to the definition of Standard Output Sensitivity (Section 2 of Part 1)

3.1 Evaluated signal (Section 2.3 of Part 1, Rule of conditions (2))

In order to be able to measure and examine cameras available in the market, it is necessary to use the standard playback signal of personal computers instead of using the 'Y' signal preset inside the camera. It is also necessary to establish a uniform definition of luminance signal 'Y'. For that matter, color cameras have options; and this standard adopts sRGB luminance-generation coefficient set by IEC 61966-2-1. (For the sake of brevity, each digital RGB signal is expressed simply in R, G, or B, in the main text of this standard. But in fact, each digital RGB signal is the signal processed by γ conversion, and the sRGB luminance-generation coefficient should be applied to linear luminance values. With that in mind, the signal processed by γ conversion is indicated with an apostrophe bellow.)
Exif standard (ver 2.1 or earlier), which is the standard image file of digital cameras, designates a traditional matrix, Y'＝0.299R'＋0.587G'＋0.114B' as the Luminance Signal Matrix of a camera in the color-space guideline used for the signal generation. Thus, the adoption of this matrix was considered. However, Exif also designates sRGB for the target color space in a

playback system. The following luminance signal was adopted in the end:

$Y' = MAX \times \gamma\{0.2126\gamma^{-1}\{R'/MAX\} + 0.7152\gamma^{-1}\{G'/MAX\} + 0.0722\gamma^{-1}\{B'/MAX\}\}$

Max is normalization coefficient (= digital maximum output value: 255 for 8 bit)

$\gamma\{\ \}$, $\gamma^{-1}\{\ \}$ are sRGB gamma characteristics and its inversion (linearization) characteristics stipulated in IEC 61966-2-1

Y' is the luminance signal obtained from the reapplication of gamma curve to the luminance Y defined by the equation above. The equation above applies sRGB luminance-generation coefficient to luminance-linear values (R, G, B), which are obtained by adopting inverted gamma curve of each digital RGB signal (R'G'B') using the sRGB (IEC 61966-2-1).

However, neither equation has much influence on the actual measured values because the full correction of white balance is assumed. (If the photographic subject is achromatic; in other words, if the perfect white balance on the subject under test is maintained, the value obtained from the two equations above would be identical.)

Meanwhile, when mentioning sRGB, the linearized function is defined as γ in many cases, assuming a display type. However, as being in line with usage in the realm of the camera system, the function transforming into tone compressed signal from the linear signal is defined as γ in this standard, and the characteristic associated with display systems or the linearization function to restore the linear parameters is expressed as γ^{-1}.

3.2 Standard level (Section 2.3 of Part 1, Rules for Conditions (3))

In the color space of digital cameras being tested (sRGB for DCF cameras), the Y-value corresponding to 18% standard neutral gray is designated as sensitivity value when the digital maximum output (255 for 8 bit) corresponds to a reflectance rate of 100%.

The level of sensitivity in itself is voluntary, thus, though it is not tolerated at around saturation level due to the defect caused by Knee characteristics, there is no single and absolute point of definition as long as the tone is in the middle range; therefore, it becomes necessary to select some value. Needless to say, it is then necessary to consider the compliance with the Film ISO speed and exposure control system of the existing photography world. Thus, this standard adopts 18% neutral gray as a ground for selecting the standard level of sensitivity.

18% gray has long been used as the standard reflector in the photographic area for the evaluation of exposure control. This means it is set around the medium tone range. In other words, the logarithmic center (logarithmic average) is measured at 18% when maximum and minimum values of the diffuse reflectance distribution of the subject are about 98% and 3.3% respectively. In other words, the value has even latitude against excess or deficiency of exposure caused by exposure errors, and this has been used as a substitute standard for evaluation to represent general photographic subjects. Therefore, it is relatively easy to obtain compliance with the exposure control system.

4. Supplement to measurement conditions of Standard Output Sensitivity（Section 3 of Part 1）

4.1 Environmental conditions (Section 3.2 of Part 1)

The conditions are in line with ISO 12232, which stipulates that the humidity standard should be recommended, but the similar standard of ISO 14524 stipulates that it is mandatory. It has been decided that the recommendation does not have specific meaning. (There is a possibility of misstatement.)

4.2 Exposure adjustment (Section 3.4 of Part 1, Camera settings (8))

If the exposure time is too long, a dark current could be generated; and if it is too short, a smear could be superposed on the real subject signal. Thus, some restrictions are placed on the exposure time.

5. Supplement to calculation of the focal plane exposure (Section 5 of Part 1, Measurement method (4))

Unlike film, it is not possible for a user to measure the 'sensitivity' of a camera having a built-in lense without the lens. Most consumer digital cameras have a built-in lens. Even if a camera has interchangeable lenses, it is still generally difficult to know where to separate the system. (For example, it is particularly problematic when the optical system is so designed that an infrared-cut filter is mounted on the subject sidefrom the major lens in order to switch to high-sensitivity (infrared) photography). Taking these factors into consideration, a camera with a mounted lens has been designated as the basic state.

In this case, when the correction coefficient for the light-reducing effect of a lens represented by transmission factor is expressed as τ (all other elements, except for aperture, such as 'subject-distance coefficient', 'flare coefficient', and 'cosine 4 power-rule correction coefficient' are included in this definition) the exposure in the focal plane Hm is calculated as follows:

$$\mathbf{Hm} = \frac{\tau \ \mathbf{x}\ \pi \ \mathbf{x\ B\ x\ T}}{\mathbf{4\ x\ F}^2}$$

In that case, with due consideration for the compliance with other international standards such as ISO 12232 and ISO 14524 (OECF), the correction coefficient mentioned above representing a camera with mounted lens would be as follows:

$\tau \text{ x } \pi/4 = 0.65 \quad (\tau = 0.828)$

（refer to **ISO 12232 Annex B**）

6. Supplement to listing of information of White Balance (Note 3 of Annex 2)

This standard designates to keep the information on white balance as mandatory; it also stipulates that this information may be omitted on the condition that sensitivity notation is expressed. In reality, there is not much advantage of presenting such additional information since numerical influence from WB adjustment on the measurement of sensitivity is small, on the contrary, it could even cause unnecessary confusion. therefore, it is rather recommended to omit the information.

7. Supplement to measurement using open aperture (Notes 2 and 3 of Annex 3(2))

When calculating sensitivity based on the nominal open F-value, using the open aperture metering method, measurement errors may occur when the specification of open F-value is not satisfied (darker than the nominal value). The result is the lower sensitivity in calculation, and this does not give an advantage.

8. Cameras unable to measure Standard Output Sensitivity (Relating to Note 3 of Annex 3-(2))

Sensitivity is measurable in the end, if either one of the following conditions is fulfilled:

(a) An exposure value can be known. (having a manual exposure function, or otherwise, exposure value on display and/or data on image file)

(b) A gain value can be fixed.

However, if neither condition (a) nor (b) is fulfilled, the sensitivity (of the product itself without dismantlement, etc.) is not measurable (by someone other than the manufacturer).

9. Deliberation Committee

The deliberations for the drafting of this Standard were conducted mainly by a sub-working group under the Technical Working Group of the Standardization Committee, namely, the **Sensitivity Sub-Working Group.** In addition, the deliberations started in January 2000 by the Sensitivity Sub-Working Group (Chief : Hideaki Yoshida / OLYMPUS OPTICAL CO., LTD. Present OLYMPUS CORPORATION) in the Digital Camera Technology Sub-committee of the Japan Camera Industry Association (Voluntary association: resolved in June 2002), which is the former body of the Camera & Imaging Products Association, and later succeeded by the Sensitivity Sub-Working Group of this association.

The following are the committees involved in the standardization.

［Standardization Committee］

Chair	Iwao Aizawa(KONICA CORPORATION)	KONICA MINOLTA TECHNOLOGY CENTER, INC.
Vice Chair	Hideaki Yoshida(OLYMPUS OPTICAL CO., LTD.)	OLYMPUS CORPORATION
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Vice Chair	Tetsuro Goto	Nikon Corporation
Vice Chair	Toshiharu Iida	Fuji Photo Film Co., Ltd.

［Technical Working Group］

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Sub-Leader	Tadasu Ohtani	Canon Inc.

［Promotion Working Group］

Leader	Hidehiko Tanaka.	Nikon Corporation
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Sub-Leader	Akio Usui	PENTAX Corporation

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	Toshiro Kinugasa	Hitachi,Ltd.
	Isamu Hirai	PENTAX Corporation
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	Tsumoru Fukushima	Matsushita Electric Industrial Co., Ltd.
	Shigeo Sakaue	Matsushita Electric Industrial Co., Ltd.
	Toshiaki Nakahira	Ricoh Co., Ltd
	Akihiro Yoshida	Ricoh Co., Ltd

In addition, the Catalogue Sub-Working Group in the Propagation Working Group has collaborated on the consideration of the items in this Standard.

［Catalogue Sub-Working Group］

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Sub-chief	Mitsuo Matsudaira	Canon Inc.
Member	Kazuki Enomoto	OLYMPUS CORPORATION
	Hiroe Kuboki(OLYMPUS OPTICAL CO., LTD.)	-----
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