INTERNATIONAL STANDARD

# ISO 17321-1

Second edition
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# Graphic technology and photography — Colour characterisation of digital still cameras (DSCs) —

## Part 1: Stimuli, metrology and test procedures



*Technologie graphique et photographie — Caractérisation de la couleur des appareils photonumériques —*

*Partie 1: Stimuli, métrologie et modes opératoires d'essai*



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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 17321-1 was prepared by Technical Committee ISO/TC 42, *Photography,* in collaboration with ISO/TC 130, *Graphic technology*.

This second edition cancels and replaces the first edition (ISO 17321-1:2006), of which it constitutes a minor revision with the following changes:



— in 4.3.3.4.2, the typographical error “senor image area” was corrected to “sensor image area”;

— in B.2.6, a broken link to tools for non-linear optimization has been updated.



ISO 17321 consists of the following parts, under the general title *Graphic technology and photography — Colour characterization of digital still cameras (DSCs)*:

— *Part 1: Stimuli, metrology and test procedures*

— *Part 2: Considerations for determining scene analysis transforms* [Technical Report]

 

# Introduction

The spectral responses of the colour analysis channels of digital still cameras (DSCs) do not, in general, match those of a typical human observer, such as defined by the CIE standard colorimetric observer. Nor do the responses of different DSCs ordinarily match each other. In characterizing DSCs, it is therefore necessary to take account of the DSC spectral sensitivities, illumination, and encoding colour space. This part of ISO 17321 will begin to address these considerations. This part of ISO 17321 defines stimuli (spectral illumination or a colour target), metrology and photographic test procedures for acquiring DSC characterization data. It specifies test procedures for “scenes”, the most general picture taking conditions where metameric colours and a range of illumination sources are encountered. It also specifies test procedures for hardcopy “originals”, a more narrowly defined picture-taking condition in which the illumination source and the colorants being imaged are pre-defined.

ISO 17321 will distinguish among several possible image representations in different colour encodings as depicted in Figure 1 which shows the diagram of a generic image workflow for digital photography.

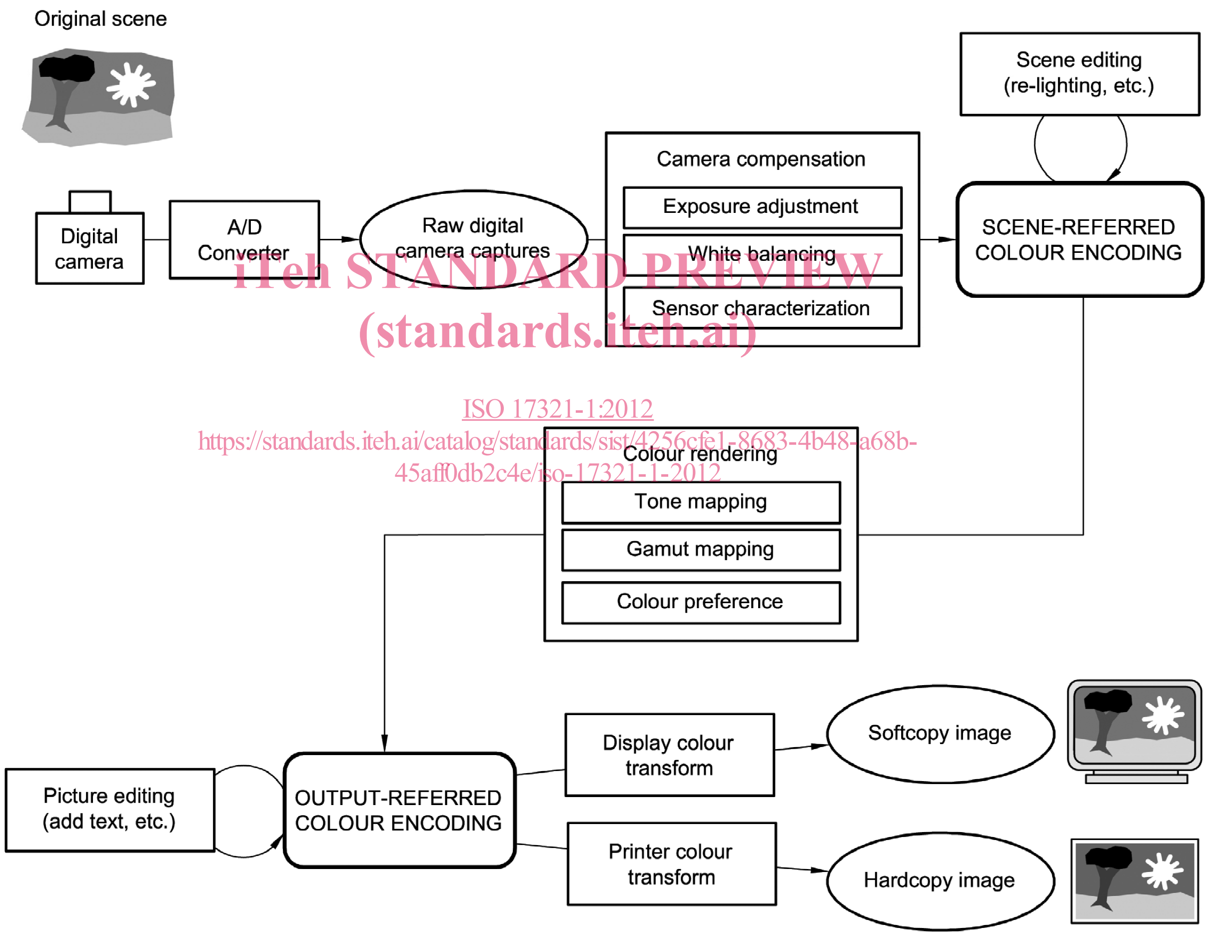




**Figure 1 — Generic image workflow for digital photography**

The DSC characterizations obtained using this part of ISO 17321 will be applicable to raw (sensor-referred) DSC data. Two alternative methods are described for obtaining these characterization data. Method A, the spectral method, uses spectral lights as stimuli for measuring the colour performance of a DSC. Method B, the target method, involves the use of a physical colour test target under specific lighting conditions to measure DSC colour performance. Annexes A to C recommend a laboratory set-up for photographing reflection targets, provide target patch selection criteria, and provide a digital still camera metamerism index.

Some operations (colour pixel reconstruction, flare removal, white balancing) can be performed without disqualifying the DSC data as being raw. However, operations that render the image data so that they become output-referred (ready to display or to print) generally do disqualify the data. With such cameras, this standard can only be applied if the capability exists to extract or to regenerate raw data, e.g. by applying the inverse of the rendering transform or by tapping the appropriate signals internal to the camera.

The technical experts who have developed this part of ISO 17321 recognize that a standard that could be applied generally to any (not just raw) DSC output would be desirable. Such a standard is problematic for DSCs that employ colour-rendering algorithms in order to produce output-referred image data. For such DSCs, it would frequently be impossible to determine if colour analysis errors relative to the scene or original captured were due to sensor image encoding errors or to proprietary colour rendering algorithms. The only way to make this distinction is if the colour rendering used is well documented and available, and the rendered data can be converted to un-rendered data by inverting the colour rendering. This situation is unlikely to occur because one of the major differentiators in DSC performance is the colour rendering. Sophisticated colour-rendering algorithms can be image dependent, and locally varying within an image. This makes it extremely difficult to reliably determine the exact colour rendering used by analysing captured test scenes.

The purpose of this part of ISO 17321 is both to assist in the characterization of DSCs for colour management purposes and to assist camera manufacturers in the determination of the colour analysis capabilities of DSCs that they are developing. This standard is applicable to any DSC intended for photographic or graphic technology applications. However, for many users it is not practical to apply this part of ISO 17321 to individual DSCs. Some of the measurements described in this part of ISO 17321 require complex, expensive measurement equipment. In the case of test targets that are commercially produced, spectral as well as colorimetric measurement data would ideally accompany the target.



Those unfamiliar with this part of ISO 17321 are encouraged to read through the entire standard (in particular the informative annexes) before proceeding with DSC characterization, in order to verify appropriateness for their particular application. In some cases, the procedures described in the multimedia standard, IEC 61966-9[5] might be more applicable.



It is proposed that other parts of ISO 17321 will be developed in the future to deal with other aspects of the colour characterization of digital still cameras.

# Graphic technology and photography — Colour characterisation of digital still cameras (DSCs) —

## Part 1:
## Stimuli, metrology and test procedures

## 1 Scope

This part of ISO 17321 specifies colour stimuli, metrology, and test procedures for the colour characterization of a digital still camera (DSC) to be used for photography and graphic technology. Two methods are provided, one using narrow spectral band illumination and the other using a spectrally and colorimetrically calibrated target. Except for a specific set of permitted data operations, these DSC data are raw.

This part of ISO 17321 does not specify the methods for deriving transformations from raw DSC data in order to estimate scene colorimetry.

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

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

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

## 3 Terms and definitions

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

**3.1**
**adopted white**
spectral radiance distribution as seen by an image capture or measurement device and converted to colour signals that are considered to be perfectly achromatic and to have an observer adaptive luminance factor of unity; i.e. colour signals that are considered to correspond to a perfect white diffuser

[ISO 22028-1]

NOTE 1 The adopted white can vary within a scene.

NOTE 2 No assumptions can be made concerning the relation between the adapted or adopted white and measurements of near perfectly reflecting diffusers in a scene, because measurements of such diffusers will depend on the illumination and viewing geometry, and other elements in the scene that can affect perception.

 

**3.2**
**digital still camera**
**DSC**
device that incorporates an image sensor and that produces a digital signal representing a still picture

NOTE A digital still camera is typically a portable, hand-held device. The digital signal is usually recorded on a removable memory, such as a solid-state memory card or magnetic disk.

**3.3**
**opto-electronic conversion function**
**OECF**
relationship between log of input levels and corresponding digital output levels for an opto-electronic digital image capture system

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

**3.4**
**raw DSC image data**
image data produced by, or internal to, a DSC that has not been processed, except for A/D conversion and the following optional steps:

— linearization,

— dark current/frame subtraction,

— shading and sensitivity (flat field) correction,

— flare removal,

— white balancing (e.g. so the adopted white produces equal RGB values or no chrominance),

— missing colour pixel reconstruction (without colour transformations)



**3.5**
**spectrally non-selective**
exhibiting reflective or transmissive characteristics that are constant over the wavelength range of interest

## 4 DSC colour characterization methods

### 4.1 General

Two methods are specified for obtaining raw DSC colour characterization data, a spectral method and a target method. The method that is most applicable in any particular situation depends on a variety of factors including, but not limited to, the following:

— the extent of one's prior knowledge about the spectral content of the scenes or originals to be captured;

— the equipment available;

— the accuracy required.

The spectral method requires elaborate equipment in a laboratory environment, but can be used to produce characterization data for samples with arbitrary spectral distributions. The target method is suitable for studio and field use, but can only provide accurate characterization data to the extent that the target spectral characteristics match those of the scene or original to be photographed.

 

## 4.2 Spectral sensitivity-based characterization — Method A

### 4.2.1 Equipment

#### 4.2.1.1 General

Spectral sensitivity-based characterization measurements shall be obtained by using a light source and monochromator to evenly illuminate a diffuse transmissive or reflective surface with electromagnetic radiation (light) containing a limited range of wavelengths centred on selected wavelengths, as specified in 4.2.3. Integrated relative radiance measurements of the illuminated surface shall be obtained for each selected wavelength using a radiance or irradiance meter with a spectral sensitivity calibration accurate to within 0,1 % and traceable to a national standards laboratory.

#### 4.2.1.2 Light source

The light source shall output radiation where the power is a smooth function of the wavelength, such as that obtained from a quartz-halogen source. Light sources that have strong emission lines shall not be used.

NOTE A fluorescent lamp is a typical light source with strong emission lines.

#### 4.2.1.3 Monochromator spectral sampling and band pass

The bandpass of the illuminating instrument (monochrometer) shall be 5 nm or narrower. The sampling interval shall not be greater than the bandpass. The monochromator should exhibit an approximately triangular band pass, with the full width at half-maximum wavelength range approximately equal to the sample spacing. The integrated radiance at all wavelengths more than 10 nm from the peak wavelength on which the monochromator is set shall be less than 1/1 000, and should be less than 1/10 000, of the integrated radiance within 10 nm of the peak radiance. Interference filters or a double monochromator may be used to meet this requirement.



#### 4.2.1.4 Illuminated surface

The illuminated surface should be the interior of an integrating sphere. It is recommended to obtain an integrating sphere with three ports close together. A transmissive diffuser is placed over one port, and illuminated by the monochromator. This produces an even illumination on the interior of the sphere. The second port is for the DSC, and the third port is for the radiance or irradiance meter. Other evenly illuminated surfaces may be used, but it is the responsibility of the user to ensure such surfaces do not have characteristics that could influence the measurements. In all cases, stray light shall be prevented from entering the integrating sphere or camera.

NOTE 1 This can be achieved by carefully enclosing the integrating sphere with the camera attached with an opaque black fabric or plastic.

NOTE 2 The radiances produced for this measurement, and for the OECF measurement described in 4.2.3, need to be comparable to those encountered in the normal operation of the digital camera.

### 4.2.2 Camera settings

Fixed exposure settings shall be selected to provide peak output levels between 50 % and 90 % of saturation. Any automatic gain or adaptive tone reproduction (analog or digital) shall be disabled, compression shall be minimized, and all user settings shall be recorded. White balancing (analog or digital) shall be fixed, so that variations in white balance do not influence the measurements. Flash should be disabled to reduce the possibility of stray light.

 

#### 4.2.3 Capturing of raw images of the output of the monochromator

The procedure for capturing raw image data using Method A shall be as follows.

a) Use a monochromator to illuminate a diffuse transmitting or reflecting surface with light centred on selected wavelengths so the illuminated area is large enough to fill the field of view of the DSC. The radiance fall-off at the DSC focal plane should be even, constant as the monochromator peak wavelength is changed, and circularly symmetric with the radiance at the edge no less than 70 % of the radiance at the centre.

b) Use a radiance or irradiance meter to measure the relative radiance of the illuminated surface as a function of wavelength.

c) Capture images of the illuminated surface at wavelengths ranging from 360 nm to at least 830 nm, and preferably to 1 100 nm in 10 nm or smaller increments. The DSC shall be set up as described in ISO 14524 for alternative focal plane OECF measurements. The images shall be captured with the DSC lens and any filters used for general picture taking (such as an infrared blocking filter) in place. The data output by each colour analysis channel of the DSC shall remain independent, i.e. not be matrixed. The relative radiance of the surface shall also be recorded for each image. Where the DSC under test can be shown to have essentially no sensitivity at wavelengths within the above wavelength ranges, these ranges may be truncated appropriately.

d) Determine the alternative focal plane OECF of the DSC in accordance with ISO 14524, except that the measurement may be performed at the peak sensitivity wavelength for each colour analysis channel.

#### 4.2.4 Post-processing of the data



Use the inverse alternative focal plane OECF to linearize the raw DSC responses at each wavelength. Average a 64 × 64 pixel block of values at the centre of each image to determine the linearized DSC response at each wavelength.



#### 4.2.5 Calculation of the relative spectral sensitivities of the DSC

Calculate the relative spectral sensitivities at each wavelength for each colour analysis channel by dividing the linearized DSC response by the relative surface radiance. Optionally, DSC relative response values for various scene spectral radiances may be calculated by taking the scalar product of the spectral radiance and the spectral sensitivity vectors for each DSC colour channel (see Annex D for more information).

Normalize the spectral sensitivities so the sum of the green channel sensitivities is unity. A different channel may be normalized to unity if so reported.

NOTE If desired, the OECF of each channel, as measured in accordance with ISO 14524, can be used to determine absolute spectral sensitivities from the relative spectral sensitivities.

#### 4.2.6 Data reporting

The data shall be reported in tabular form, with the relative spectral sensitivity reported for each channel at each selected wavelength.

### 4.3 Target-based characterization — Method B

#### 4.3.1 General

The method to be used for the collection of target-based characterization data consists of imaging a reflective or transmissive colour target of known spectral and colorimetric characteristics, under specified illumination, recording the output of the DSC for each patch, and providing these data for subsequent processing.

NOTE When target-based characterization is used, the resultant characterization data is only applicable for similar geometric and spectral illumination characteristics.

### 4.3.2 Test target

The choice of test target to be used shall be a decision of the individual doing the characterization and may be a commercially available target or a custom target developed for the purpose of digital still camera characterization. Annex C provides a listing of some of the characteristics that should be considered in developing an ideal target for DSC characterization.

Regardless of the target used it shall have available a tabulation of the spectral reflectance factor or spectral transmittance factor for each patch. This data shall be from at least 380 nm to 730 nm at least at every 10 nm and should be from 360 nm to 830 nm at least at every 10 nm. In addition, colorimetric values for all of the colour patches should be included. Measurements and computation of colorimetric parameters shall be in accordance with ISO 13655. The use of telephoto-spectrometer from the identical position where the camera is set is preferred.

Where the DSC under test can be shown to have essentially no sensitivity at wavelengths within the above wavelength ranges, the target measurement requirements may be truncated appropriately.

NOTE 1 Two commonly available commercial targets that many have used for this application are the traditional 24 patch ColorChecker and the 237 patch ColorChecker DC Digital Camera Color Reference Chart. (ColorChecker is the trade name of a product supplied by GretagMacbeth. This information is given for the convenience of users of this part of ISO 17321 and does not constitute an endorsement by ISO of the product named. Equivalent products can be used if they can be shown to lead to the same results.)



NOTE 2 If measurements are not performed to 830 nm, there is a possibility that unwanted IR sensitivity will not be identified during subsequent testing. One approach is to separately look at the transmittance of any UV and IR blocking filters, the basic DSC filters, and the response of the detector itself. Another approach is illustrated by the example in ISO 14524 which provides a method for evaluating the sensitivity of a DSC to IR radiation.



### 4.3.3 Test procedure

#### 4.3.3.1 Test target illumination

##### 4.3.3.1.1 For laboratory characterization using a reflection target

The spectral power distribution for illuminating the test target shall be photographic daylight D55, as defined in ISO 7589. The illuminance at the target plane should be between 2 000 lx and 4 000 lx and have a maximum variation of 1 % over the area being imaged. Annex A outlines a recommended laboratory set-up for photographing a colour reflection test target.

The primary axis of the incident illumination should be approximately 45° to the normal to the centre of the target area being imaged. Two or more illumination sources, which are equally spaced around the normal to the centre of the area of the target that is being measured, should be used.

NOTE With the optical axis of the DSC normal to the test target, this will help to minimize the probability of specular reflections entering the field of view of the DSC.

In qualifying the illumination source, particular attention should be paid to the rolloff in red response. The spectral distribution index (SDI) described in ISO 7589 assumes a rolloff in red response which is normal with silver halide films, but does not naturally occur with typical DSC sensors. If a DSC has a long wavelength red response that is significantly different from that assumed in ISO 7589, the SDI criterion is possibly not sufficient for qualifying the illumination source. ISO 14524:2009, Annex B, also contains information about the relevancy of SDI calculations to the qualification of illumination sources for DSCs. If there is some question about the relevancy of the SDI, the illumination source used should be chosen so that its spectral power distribution matches that of the desired source as closely as possible, in addition to meeting the SDI criterion.

If it is determined that an IR blocking filter is required for OECF determination, in accordance with ISO 14524, the long wavelength red and infrared response of the DSC should be checked to determine if the response is being appropriately dealt with by the DSC's filters. If the DSC shows abnormally high long wavelength red response (see the standard red rolloff in ISO 7589), or significant near infrared response, additional filters can be used with the DSC at all times. It is also possible that the illumination source can be emitting excessive amounts of infrared radiation, in which case the IR blocking filter should be placed on the source, and the source requalified. If measurements of the DSC spectral response to wavelengths from 840 nm to 1 100 nm were obtained, these spectral response values can be used to further qualify the infrared rejection of the DSC. The ratio of the sum of spectral responses from 360 nm to 730 nm to the sum of spectral responses from 740 nm to 1 100 nm should be greater than the ISO DSC luminance dynamic range, as measured in accordance with ISO 15739[3].

#### 4.3.3.1.2 For *in situ* characterization

When the DSC is to be characterized *in situ*, the illumination source to be used for actual imaging shall be used. This can be the digital still camera's own illumination, studio illumination, backlighting for transparent targets, or natural light (either artificial or daylight).

Where possible, the primary axis of the incident illumination for a reflection target should be approximately 45° to the normal to the centre of the target area being imaged. Two or more illumination sources, which are equally spaced around the normal to the centre of the area of the target that is being measured, should be used.



NOTE Placing the optical axis of the DSC normal to the surface of a reflection test target will help to minimize the probability of specular reflections entering the field of view of the DSC.

#### 4.3.3.2 Camera focusing



The target distance is dictated by the size of the target, the field of view of the camera, and the focal length(s) of the camera lens. These should be chosen such that the DSC is in sharp focus for the resulting target distance.

#### 4.3.3.3 Camera settings

For DSC characterizations performed in laboratory settings, the flash shall be turned off, any automatic gain control shall be disabled, compression shall be minimized, and all user settings shall be recorded. If possible, any digital white balancing should be turned off and any analog white balancing should be fixed, so that variations in the analog white balance do not confound the white balance of the raw DSC data revealed by the OECFs.

For DSC characterizations performed *in situ*, compression shall be minimized, and all user settings shall be recorded. While local conditions can require the use of automatic gain control, if possible it should be disabled. If possible, any digital white balancing should be turned off and any analog white balancing should be fixed, so that variations in the analog white balance do not confound the white balance of the raw DSC data revealed by the OECFs.

#### 4.3.3.4 Image capture geometry

#### 4.3.3.4.1 Full frame image capture

If full frame image capture is to be used, the test target should be framed within the DSC field of view so that the set of fiducial marks appropriate for the aspect ratio of the DSC end up just inside the corners of the captured image.

NOTE In the case of *in situ* characterization, the target can, of necessity, occupy a smaller portion of the captured image.

 