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Photography — Electronic still-picture cameras — Resolution measurements

Photographie — Appareils de prises de vue électroniques — Mesurages de la résolution

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Foreword

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

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

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

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

International Standard ISO 12233 was prepared by Technical Committee ISO/TC 42, *Photography*.

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

0 Introduction

0.1 Purpose

The spatial resolution capability is an important attribute of an electronic still-picture camera. Resolution measurement standards allow users to compare and verify spatial resolution measurements. This International Standard defines terminology, test charts and test methods for performing resolution measurements for analog and digital electronic still-picture cameras.

0.2 Technical background

One of the most important characteristics of an electronic still-picture camera is the ability of the camera to capture fine detail found in the original scene. This ability to resolve detail is determined by a number of factors, including the performance of the camera lens, the number of addressable photoelements in the optical imaging device, and the electrical circuits in the camera, which may include image compression and gamma correction functions. Different measurement methods can provide different metrics to quantify the resolution of an imaging system, or a component of an imaging system, such as a lens. Resolution measurement metrics include resolving power, limiting resolution (at some specified contrast), spatial frequency response, MTF and OTF.

The first step in measuring resolution is to capture an image of a suitable test-chart with the camera under test. The test chart should include patterns with sufficiently fine detail, such as edges, lines, square waves, or sine wave patterns. The test chart defined in this International Standard has been designed specifically to evaluate electronic still-picture cameras. It has not been designed to evaluate other electronic imaging equipment such as input scanners, CRT displays, hard-copy printers, or electrophotographic copiers, nor individual components of an electronic still-picture camera, such as the lens.

The resolution measurements described in this International Standard are performed in the digital domain, using digital analysis techniques. For electronic still-picture cameras that include only analog outputs, the analog signal needs to be digitized, so that the digital measurement can be performed. The digitizing equipment is characterized, so that the effects of the digitization process can be removed from the measurement results. When this is not possible, the type of digitizing equipment used shall be reported along with the measurement results.

The spatial frequency response (SFR) measurement method described in this International Standard uses a computer algorithm to analyse digital image data from the electronic still-picture camera. Digitized image values near slanted vertical and horizontal black to white edges are digitized and used to compute the SFR values. The use of a slanted edge allows the edge gradient to be measured at many phases relative to the image sensor photoelements, in order to eliminate the effects of aliasing. This technique is mathematically equivalent to performing a moving knife edge measurement.

Photography — Electronic still-picture cameras — Resolution measurements

1 Scope

This International Standard specifies methods for measuring the resolution of electronic still-picture cameras. It is applicable to the measurement of both monochrome and colour cameras which output digital data or analog video signals.

2 Normative references

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

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

ISO 14524:1999, Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs).

3 Terms and definitions

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

3.1
addressable photoelements
number of active photoelements in an image, which is equal to the number of active lines of photoelements multiplied by the number of active photoelements per line

NOTE It is possible that the number of addressable photoelements may be different for the different colour records of an image. When the signal values of the photoelements are digitized, the digitized code values may be referred to as picture elements, or pixels.

3.2
aliasing
output image artifacts that occur in a sampled imaging system for input images having significant energy at frequencies higher than the Nyquist frequency of the system

3.3
cycles per millimetre
cy/mm
unit used for specifying resolution characteristics in terms of the response of an imaging system to a linear radiance sine wave input, as a function of the frequency of the sine wave

NOTE 1 A range of input sine wave frequencies is obtained in this International Standard through the use of a sharp edged target.

NOTE 2 Most pictorial imaging systems exhibit non-linear behaviour, which may result in the nature of the target affecting the measured resolution characteristics. Distance units other than millimetres may also be used.

3.4
aliasing ratio
value equal to the "maximum minus minimum" modulation divided by the "average" modulation of an electronic still-picture camera when imaging a frequency burst of constant spatial frequency

NOTE The aliasing ratio is described in 6.4.

3.5
edge spread function
ESF
normalized spatial signal distribution in the linearized output of an imaging system resulting from imaging a theoretical infinitely sharp edge

3.6
effectively spectrally neutral
having spectral characteristics which result in a specific imaging system producing the same output as for a spectrally neutral object

3.7
electronic still-picture camera
camera incorporating an image sensor that outputs an analog or digital signal representing a still-picture, or records an analog or digital signal representing a still-picture on a removable media, such as a memory card or magnetic disc

3.8
gamma correction
process that alters the image data in order to modify the tone reproduction

3.9
horizontal resolution
resolution value measured in the longer image dimension, corresponding to the horizontal direction for a "landscape" image orientation, typically using a vertically oriented test-chart feature

3.10
image aspect ratio
ratio of the image width to the image height

3.11
image compression
process that alters the way digital image data is encoded in order to reduce the size of an image file

3.12
image sensor
electronic device that converts an optical image into an electronic signal; for example a charge coupled device (CCD) array

3.13
limiting resolution
value of that portion of a specified resolution test pattern, measured in line widths per picture height, that corresponds to an average modulation value equal to some specified percentage of the modulation value at a specified reference frequency

EXAMPLE The limiting resolution may be the test pattern value, in line widths per picture height (LW/PH), corresponding to a camera output modulation level of 5 % of the camera output modulation level at a reference frequency of 10 LW/PH.

3.14
line pairs per millimetre
lp/mm
metric for specifying resolution in terms of the number of equal width black and white line pairs per millimetre that can be resolved according to some criterion, such as visual resolution or limiting resolution

NOTE distance units other than millimetres may also be used.

3.15
lines per millimetre
lines/mm
metric for specifying resolution in terms of the number of equal-width black and white lines per millimetre that can be resolved according to some criterion, such as visual resolution or limiting resolution

NOTE Distance units other than millimetres may also be used.

3.16
line spread function
LSF
normalized spatial signal distribution in the linearized output of an imaging system resulting from imaging a theoretical infinitely thin line

NOTE If the imaging system is operating in an isoplanatic region and in its linear range, the LSF is equal to the first derivative of the ESF.

3.17
line widths per picture height
LW/PH
metric for specifying the width of a solid line on a test chart, relative to the height of the active area of the chart, which is equal to the height of the active area of the test chart divided by the width of a black line, that is equal to the total number of lines of the same width which can be placed edge to edge within the height of a test target, or within the vertical field of view of a camera

NOTE If the height of the active area of the chart equals 20 cm, a black line of 1 000 LW/PH has a width equal to 20/1 000 cm.

3.18
linearized
digital signal conversion performed to invert the camera opto-electronic conversion function (OECF) so that the resulting signal is approximately linearly proportional to the scene luminance

3.19
modulation
difference between the minimum and maximum signal levels divided by the sum of these levels

3.20
modulation transfer function
MTF
modulus of the optical transfer function

3.21
normalized spatial frequency
unit used for expressing spatial frequency response, where the distance dimension has been removed by multiplying the spatial frequency in cycles per millimetre by the sampling period in millimetres

NOTE Normalized spatial frequency is particularly appropriate for comparing the spatial frequency response of imaging systems where the rendering magnification is unknown, and the total number of samples is equal.

3.22
Nyquist limit
spatial frequency equal to 1/2 times the inverse of the sampling period

NOTE Energy at an input spatial frequency above the Nyquist limit will alias to a spatial frequency below the Nyquist limit in the output image. The Nyquist limit may be different in the two orthogonal directions.

3.23
optical transfer function
OTF
two-dimensional Fourier transform of the imaging system's point spread function

NOTE 1 For the OTF to have significance, it is necessary that the imaging system be operating in an isoplanatic region and in its linear range.

NOTE 2 The OTF is a complex function whose modulus has unity value at zero spatial frequency.

3.24
point spread function
PSF
normalized spatial signal distribution in the linearized output of an imaging system resulting from imaging a theoretical infinitely small point source

3.25
resolution
measure of the ability of a camera system, or a component of a camera system, to depict picture detail

NOTE Resolution measurement metrics include resolving power, limiting resolution, spatial frequency response (SFR), MTF and OTF.

3.26
sampling aspect ratio
ratio of the sample spacing in the two orthogonal sampling directions

NOTE If the sample spacing is equal, the aspect ratio of the sampling grid is 1:1 or "square", so that the sampling aspect ratio provides "square pixels".

3.27
sampled imaging system
imaging system or device which generates an image signal by sampling an image at an array of discrete points, or along a set of discrete lines, rather than a continuum of points

NOTE The sampling at each point is done using a finite size sampling aperture or area.

3.28
sample spacing
physical distance between sampling points or sampling lines

NOTE The sample spacing may be different in the two orthogonal sampling directions.

3.29
spatial frequency response
SFR
measured amplitude response of an imaging system as a function of relative input spatial frequency

NOTE 1 The SFR is normally represented by a curve of the output response to an input signal of unit amplitude, over a range of spatial frequencies.

NOTE 2 The SFR is normalized to yield a value of unity at a spatial frequency of 0.

3.30
spectrally neutral
test chart is spectrally neutral if the relative spectral power distributions of the incident and reflected (or transmitted) light are equal

3.31
test chart
arrangement of test patterns designed to test particular aspects of an imaging system

3.32
test pattern
specified arrangement of spectral reflectance or transmittance characteristics used in measuring an image quality attribute

The test pattern spectral characteristics include the following types:

3.32.1
bi-tonal pattern
pattern that is spectrally neutral or effectively spectrally neutral, and consists exclusively of two reflectance or transmittance values in a prescribed spatial arrangement

NOTE Bi-tonal patterns are typically used to measure resolving power, limiting resolution and SFR.

3.32.2
grey scale pattern
pattern that is spectrally neutral or effectively spectrally neutral, and consists of a large number of different reflectance or transmittance values in a prescribed spatial arrangement

NOTE Grey scale patterns are typically used to measure opto-electronic conversion functions.

3.32.3
spectral pattern
pattern that is specified by the spatial arrangement of features with differing spectral reflectance or transmittance values

NOTE Spectral patterns are typically used to measure colour reproduction.

3.33
vertical resolution
resolution value measured in the shorter image dimension, corresponding to the vertical direction for a "landscape" image orientation, typically using a horizontally oriented test-chart feature

3.34
visual resolution
spatial frequency at which the individual black and white lines of a test pattern reproduced on a display or print can no longer be distinguished by human observers, or are reproduced at a spatial frequency lower than the spatial frequency of the corresponding area of the test chart, as a result of aliasing

4 Test chart

4.1 Introduction

A reproduction of a test chart for measuring the resolution of an electronic still-picture camera is shown in Figure 1. Figure 2 is a diagram showing the locations of particular features of the test chart, which may be either a reflective or transmissive chart. The purpose of each test pattern element is listed in Table 1. A complete spreadsheet specification of the test chart is given for information in annex A.

The measurements described in clause 6 can be performed using test charts other than the chart shown in Figure 1. For example, the test patterns present in the test chart can be separated and rearranged, if required, for specific test objectives. The framing and the reproduction scale of the patterns can also be varied, if required, for specific test objectives.

The chart shown in Figure 1 is designed to measure cameras having a limiting resolution of less than 2 000 LW/PH. Nevertheless, it is possible to use the chart to measure the visual resolution or limiting resolution of an electronic still camera having a limiting resolution greater than 2 000 LW/PH. This is accomplished by adjusting the camera to target distance, or the focal length of the camera lens, so that the test-chart active area fills only a fraction of the vertical image height of the camera. This fraction is then measured in the digital image, by dividing the number of image lines in the camera image by the number of lines in the active chart area. The values of all test-chart features, in LW/PH, printed on the chart or specified in this International Standard, are multiplied by this fraction, to obtain their correct values. For example, if the chart fills 1/4 of the vertical image height of the camera, a feature labelled as 1 000 LW/PH on the chart corresponds to 4 000 LW/PH using this chart framing.

4.2 Material

The test chart may be either a transparency that is rear illuminated, or a reflection test card that is front illuminated. A reflection chart shall have an approximately Lambertian base material. A transparency chart shall be rear illuminated by a diffuse source.

4.3 Size

The active height of reflection test charts should be not less than 20 cm. The active height of transparencies shall be not less than 10 cm. The chart should have a 16:9 image aspect ratio, with indicators for 1:1, 4:3 and 3:2 image aspect ratios.

4.4 Test patterns

The test chart shall have bi-tonal patterns and should be spectrally neutral.

NOTE Use of bi-tonal test charts provides the sharpest possible features and minimizes the cost of producing the chart.

4.5 Test-pattern modulation

For reflectance charts, the ratio of the maximum chart reflectance R_{max} to the minimum chart reflectance R_{min} for large test-pattern areas should be not less than 40:1 and not greater than 80:1, and shall be reported if it is outside this range. For transmissive charts, the ratio of the maximum chart transmittance T_{max} to the minimum chart transmittance T_{min} for a large test pattern should be not less than 40:1 and not greater than 80:1, and shall be reported if it is outside this range. Modulation ratios for the finer test-chart features, relative to the ratio for large test-pattern areas, should preferably be reported by the chart manufacturer as described in annex B, so that these values may be used to correct the SFR values measured using the chart.

4.6 Units

All test-chart features are specified in units of line widths per picture height (LW/PH), where the height is the active image distance in the shorter test-chart dimension.

NOTE This allows measurements to be reported using units that are independent of the sample spacing and the image aspect ratio.

4.7 Features

The test chart should include horizontal, vertical and diagonally oriented hyperbolic wedges, sweeps and tilted bursts. It may also include a circle and long, slightly slanted lines to measure geometric linearity (distortion).

NOTE The finest features are 2 000 LW/PH, which is equivalent to 1 000 line pairs per picture height.

4.8 Positional tolerance

The position of any test-chart feature shall be proportional to the values given in normative annex C and shall be reproduced with a tolerance of ± 1/1 000 picture heights (equivalent to ± 1/10 % of the active test-chart height). In addition, the width and duty cycle ratio of each feature (white or black line) of J, JS, K, KS, O and P in Figure 2 shall be reproduced with a tolerance of ± 5 % of the feature width.

This tolerance requires all test-chart features to be accurately located to with ± 2/10 mm for a test-chart height of 20 cm. In addition, the width of the white or black lines comprising the 2 000 LW/PH portion of K1 are required to fall within the range of 1/2 000 ± 5 % of the actual test-chart height, equal to 95/1 000 mm to 105/1 000 mm for a test-chart height of 20 cm.

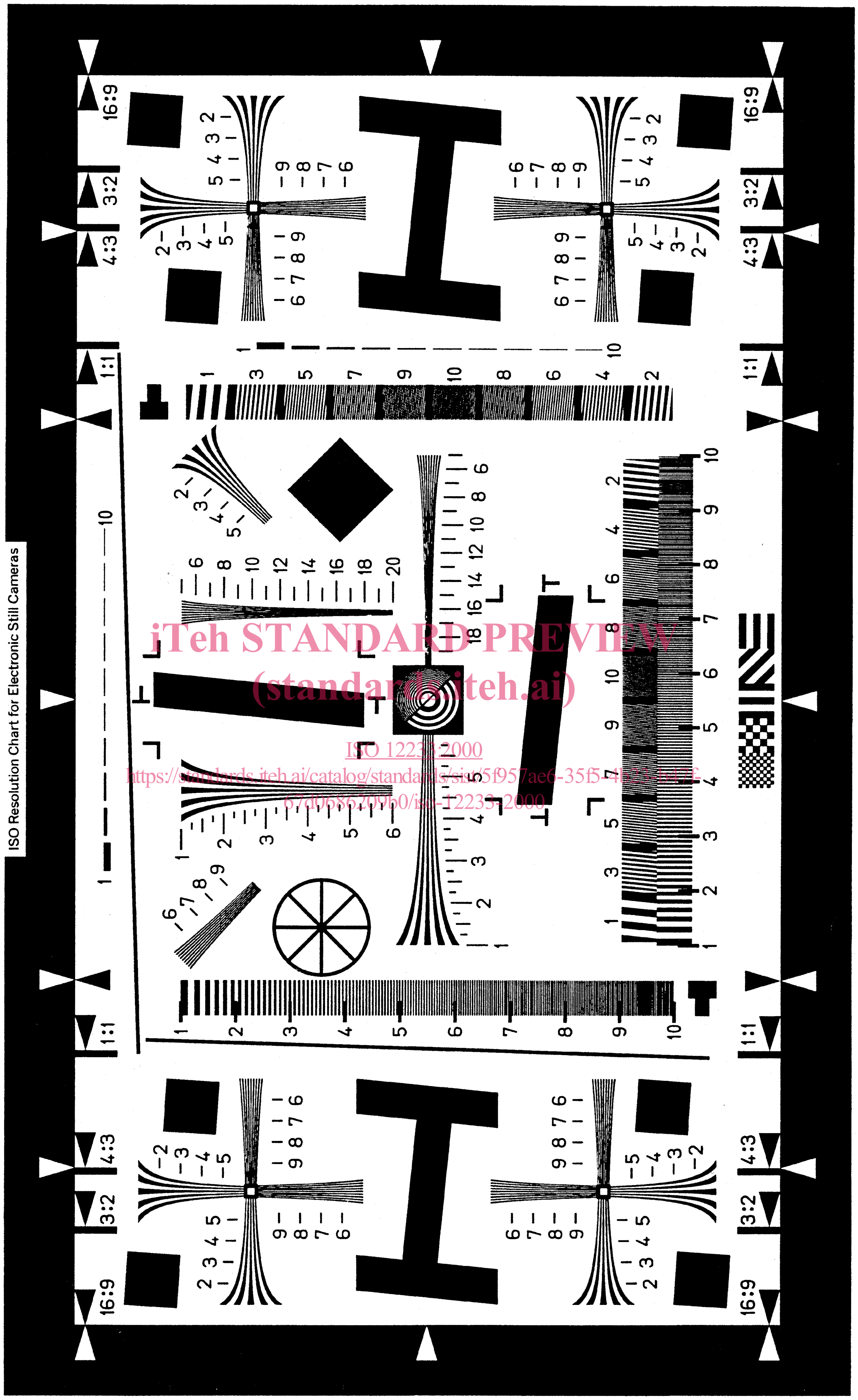

Figure 1 — Resolution test chart