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Photography — Electronic scanners for photographic images — Dynamic range measurements

Photographie — Scanners électroniques pour images photographiques — Mesurages d'intervalles dynamiques

Reference number
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Foreword

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ISO 21550 was prepared by Technical Committee ISO/TC 42, *Photography*.

Introduction

The use of scanners to provide digital image files is rapidly growing. A standard is needed in order to measure the ability of scanners to capture tones especially in the dark areas of the original. At the present time most manufacturers calculate the dynamic range from the bit depth of the implemented A/D conversion which is usually higher than the actual capabilities of the scanner. This International Standard can be used for photofinishing, professional, graphic arts and consumer scanners.

This International Standard specifies methods for measuring the ability of scanners to capture tones especially in the dark areas of the original. The scanner measurements described in this International Standard are performed in the digital domain, using digital analysis techniques. A test chart of appropriate size and characteristics is scanned and the resulting data is analysed. The test chart described in this International Standard is designed specifically to evaluate continuous tone film and reflection scanners. It is not designed for evaluating electronic still-picture cameras, video cameras, or bi-tonal document scanners.

Photography — Electronic scanners for photographic images — Dynamic range measurements

1 Scope

This International Standard specifies methods for measuring and reporting the dynamic range of electronic scanners for continuous tone photographic media. It applies to scanners for reflective and to scanners for transmissive media.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

ISO 12231, *Photography — Electronic still-picture cameras — Terminology*

ISO 12232:1998, *Photography — Electronic still-picture cameras — Determination of ISO speed*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12231 and the following apply.

3.1
addressable photoelements
number of active photoelements in an image sensor

NOTE This is equal to the number of active lines of photoelements, multiplied by the number of active photoelements per line.

3.2
aliasing
output image artefacts 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
digital output level
numerical value assigned to a particular output level, also known as the digital code value

3.4
edge spread function
ESF
normalized spatial signal distribution in the linearized output of an imaging system resulting from imaging a theoretical infinitely sharp edge

3.5
effectively spectrally neutral
characteristic of an imaging system whereby the output is the same as that produced from a spectrally neutral object

3.6
electronic scanners for photographic film
scanner that incorporates an image sensor whose output is a digital signal that represents a still film image

3.7
fast scan direction
scan direction corresponding to the direction of the alignment of the addressable photoelements in a linear array image sensor

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

3.9
image sensor
electronic device that converts incident electromagnetic radiation into an electronic signal; e.g. a charge coupled device (CCD) array

3.10
incremental gain function
change in output level (digital code value) divided by the change in input level (luminance or exposure) as a function of input level

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

NOTE 2 If the input exposure points are very finely spaced and the output noise is small compared to the quantization interval, the incremental gain function may have a jagged shape. Such behaviour is an artefact of the quantization process and should be removed by using an appropriate smoothing algorithm, or by fitting a smooth curve to the data. In some cases it may be desirable to fit a curve to the input-output data and then determine the incremental gain function by taking the first derivative of the function used for the curve fit.

3.11
incremental output signal
input level multiplied by the system incremental gain at that level

3.12
incremental signal to noise ratio
ratio of the incremental output signal to the root-mean-squared (rms) noise level, at a particular signal level

NOTE This is typically expressed as a graph or table showing the rms noise level versus output signal level for the full range of output signal levels.

3.13
ISO scanner dynamic range
difference of the maximum density where the incremental gain is higher than 0,5, as determined according to ISO 21550 to the minimum density that appears unclipped

3.14
noise
unwanted variations in the response of an imaging system

3.15
resolution
measure of the ability of a digital image capture system, or a component of a digital image capture system, to capture fine spatial detail

NOTE Resolution measurement metrics include resolving power, limiting visual resolution, SFR, Modulation Transfer Function (MTF) and Contrast Transfer Function (CTF).

3.16
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.

3.17
sample spacing
physical distance between sampling points or sampling lines

NOTE 1 The sample spacing may be different in the two orthogonal sampling directions.

NOTE 2 Measured in units of distance (e.g. microns, mm).

3.18
sampling frequency
reciprocal of sample spacing

NOTE This is expressed in samples per unit distance [e.g. dots per inch (dpi)].

3.19
scanner
electronic device that converts a fixed image, such as a film or film transparency, into an electronic signal

3.20
scanner opto-electronic conversion function
Scanner OECF
relationship between the input density and the digital output levels for a scanner

3.21
slow scan direction
direction in which the scanner moves the photoelements (perpendicular to the lines of active photoelements in a linear array image sensor)

3.22
spatial frequency response
SFR
measured amplitude response of an imaging system as a function of relative input spatial frequency

NOTE The SFR is normally represented by a curve of the output response to an input sinusoidal spatial luminance distribution of unit amplitude, over a range of spatial frequencies. The SFR is normalized to yield a value of 1,0 at a spatial frequency of 0.

3.23
spectrally neutral
test chart equality of the relative spectral power distributions of the incident and reflected (or transmitted) light

3.24
test chart
arrangement of test patterns designed to test particular characteristics

3.25
test pattern
specified arrangement of spectral reflectance or transmittance characteristics used in measuring an image quality attribute

3.26
test pattern types

3.26.1
bi-tonal patterns
patterns that are spectrally neutral or effectively spectrally neutral, and consist 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.

3.26.2
grey scale patterns
patterns that are spectrally neutral or effectively spectrally neutral, and consist 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.

3.26.3
spectral patterns
patterns that are specified by the spatial arrangement of features with differing spectral reflectance or transmittance values

NOTE Spectral patterns are typically used to measure colour reproduction.

4 Test chart

4.1 Representation and recommended size

This section defines the type and specifications of the test chart depicted in Figure 1. This test chart can be made at various sizes to correspond to popular film sizes. The recommended size for the reflective version is 100 × 150 mm and for the transparent version it is 24 × 36 mm that corresponds to the 35 mm film format. The patches shall be arranged to minimize flare. Flare can be measured as specified in IEC 61966-8 Clause 13.

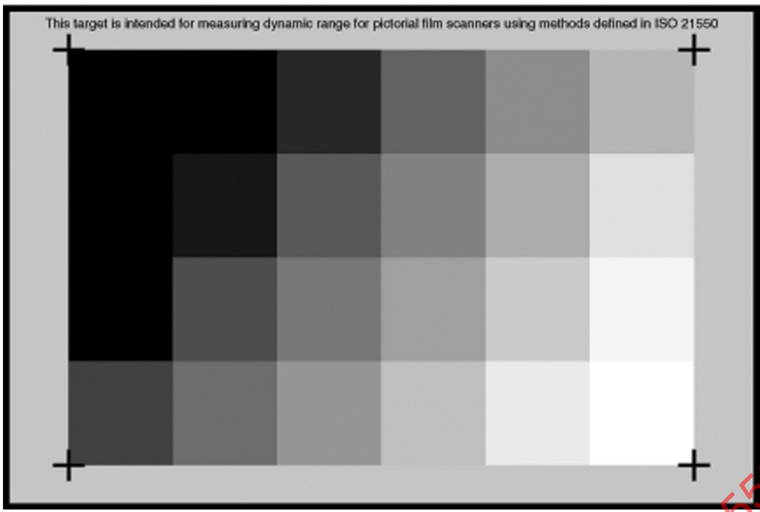


Figure 1 — Representation of the test chart

4.2 The reflective test chart

4.2.1 General characteristics of the test chart

The test chart shall be a reflection test chart based on a current monochrome photographic print material. The print material shall be spectrally neutral with tolerances as specified in ISO 14524, and resistant to fading.

The height and width of the reflection test chart should be no less than 100 mm. Additional white space may be added to the width or height to include target management data or other test chart elements not defined by this International Standard.

4.2.2 Grey scale patterns

The test chart shall include no less than 15 grey scale patterns which are necessary to measure the opto-electronic conversion function of the scanner. The density values of the grey patches shall if possible be in accordance with Annex A. The lowest density shall not be higher than 0,15 and the highest density shall be no less than 2,0. The densities shall be measured as visual densities specified in ISO 5-4.

The grey patches shall consist of a homogeneous density. The target manufacturer should state the density of each patch in a table, the density difference between the darkest and the lightest patch. The suggested form of the density table is given in Table A.1. The suggested wording for the density difference is, “This target suitable for measuring Dynamic ranges up to X.X”. For reflective targets the density range shall not be less than 1,8.

4.2.3 Fiducial marks to aid in Scanner OECF measurement

The test chart should include fiducial marks in the corners of the central target features. These marks can aid in the automatic analysis of grey patch and slanted edge features for Scanner OECF measurements.

NOTE The vertical/horizontal distance between fiducial marks in Figure 1 is 83,3/12,5 mm. This distance can be used to verify scanner sampling frequency.

4.2.4 Administrative elements

The test chart should include administrative elements to aid in tracking the genealogy and characteristics of the test chart being used. These may be items such as manufacturer's insignia, creation date, or barcode that aids in populating metadata elements.

4.3 The transparent test chart

4.3.1 General characteristics of the test chart

The test chart shall be a transmission test chart based on a current photographic film material. The film material shall be spectrally neutral with tolerances as specified in ISO 14524, and resistant to fading. If the material does not fit the tolerances, the relative spectral transmission shall be reported together with the results.

The height and width of the transparent test chart should be no less than 16,7 mm. Additional white space may be added to the width or height to include target management data or other test chart elements not defined by this International Standard.

The target manufacturer should state the Callier Q factor of the material. The Callier Q factor is given as the quotient of diffuse density and projection density. The densities to calculate the Callier Q factor shall be measured as specified in ISO 5-2. If the Callier Q factor is larger than 1,05 it shall be reported together with the dynamic range.

4.3.2 Grey scale patterns

The test chart shall include no less than 25 grey scale patterns that are necessary to measure the opto-electronic conversion function of the scanner. The density values of the grey patches shall if possible be in accordance with Annex A. The lowest density shall not be higher than 0,15 and the highest density shall be no less than 3,6. The densities shall be measured as specified in ISO 5-2.

The target manufacturer should state the density of each patch in a table, the density difference between the darkest and the lightest patch. The suggested form of the density table is given in Table A.1. The suggested wording for the density difference is, “This target suitable for Dynamic ranges up to X.X”.

4.3.3 Fiducial marks to aid in automatic SFR and Scanner OECF measurement

The test chart should include fiducial marks in the corners of the central target features. These marks can aid in the automatic analysis of grey patch and slanted edge features for Scanner OECF measurements.

NOTE The vertical/horizontal distance between fiducial marks in Figure 1 is 20/30 mm. This distance can be used to verify scanner sampling frequency.

4.3.4 Administrative elements

The test chart should include administrative elements to aid in tracking the genealogy and characteristics of the test chart being used. These may be items such as manufacturer's insignia, creation date or bar code, that aids in populating metadata elements.

5 Test conditions

5.1 General

The following measurement conditions should be used as nominal conditions when measuring the Scanner OECF. If it is not possible or appropriate to achieve these nominal operating conditions, the actual operating conditions shall be listed along with the reported results.

5.2 Temperature and relative humidity

The ambient temperature during the acquisition of the test data shall be (23 ± 2) °C, as specified in ISO 554, and the relative humidity should be (50 ± 20) %.

5.3 Luminance and colour measurements

For a colour scanner, the OECF measurements and dynamic range calculation should be performed on each output colour channel separately. If desired, a luminance OECF measurement may be made on a luminance signal formed from an appropriate combination of the colour records. In either case, the channel on which the measurement is performed shall be reported.

5.4 Scanner settings

The OECF should be measured with settings as stated in 6.1.

6 Measuring the Scanner OECF

6.1 General

The Scanner OECF shall be calculated from values determined from a test chart (Clause 4) that consists of a density range higher than the range the scanner is expected to be able to reproduce. For reflective targets, the density range shall be higher than the range of typical reflective media scanned on this scanner. Many scanners will automatically adapt to the dynamic range of the scene as reproduced on the film or reflective media and the luminance distribution of the film. The results may also differ if the scan mode is grey scale or RGB.

A minimum of 10 trials shall be conducted for each Scanner OECF determination. A trial shall consist of one scan of the test chart. For each trial, the digital output level shall be determined from a 64 × 64[1] pixel area located at the same relative position in each patch. Identical, non-aligned patches may be averaged, or the patch with the least scanning artefacts, such as dust or scan lines, may be used. The Scanner OECF so determined shall be used to calculate the resolution measurements for this trial. If the Scanner OECF is reported, the final digital output level data presented for each step density shall be the mean of the digital output levels for all the trials.

6.2 Scanner settings

The scans for the determination of the Scanner OECF shall be made in RGB or grey scale mode with a resolution set to the maximum sample frequency [given in dpi or pixels per inch (ppi)] divided by an integer to avoid interpolation.

$$R = R_{max}/k \tag{1}$$

where

R is the scanning resolution;

R_{max} is the maximum scanning resolution of the scanner;

k is integer value.

The scanner shall be set to automatic adaptation to the dynamic range and the digital values representing the dark grey patches shall be increased by applying a suitable gamma correction so that the maximum number of patches can be distinguished.

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

NOTE If the gamma is 1,0 after the automatic adaptation an enhancement to 2,0 using the scanner software in most cases leads to good results. This is similar to a modification of the gamma curve achieved by dragging the Output value 127 to a value of 180.

7 Calculation of the scanner dynamic range

7.1 Luminance OECF

A visually weighted OECF shall be derived from the red, green and blue colour records according to the following equation given in ITU-R BT.709:

$$Y_i = 0{,}212\,6 \times R_i + 0{,}715\,2 \times G_i + 0{,}072\,2 \times B_i \tag{2}$$

where

i is the number of grey patch;

Y is the visually weighted output signal.

For monochrome scans Y_i shall be equivalent to the single band data.

7.2 Scanner dynamic range

The dynamic range is calculated from the Scanner OECF by:

$$d_\mathrm{r} = d_\mathrm{max} - d_\mathrm{min} \tag{3}$$

where

d_r is the scanner dynamic range;

d_max is the density where the signal to noise ratio is 1;

d_min is the minimum density where the output signal of the luminance OECF appears to be unclipped.

7.3 Determination of the signal to noise ratio

The signal to noise ratio is determined as given in 6.2.1 of ISO 12232:1998.

$$\frac{S}{N}(X_i) = \left(\frac{T_i g_i}{\sigma_i}\right) \tag{4}$$

where

σ_i is the standard deviation of the density patch;

g_i is the incremental gain of patch i;

T_i is the transmission level of patch i;

i is the number of grey patch with i_min as lightest and i_max as darkest patch.

The transmission of a density patch is given as:

$$T_i = 10^{-d_i} \qquad (5)$$

For colour scanners with luminance and colour-difference outputs the visually weighted standard deviation of the density patches may be computed from the luminance channel standard deviation $\sigma(Y)$, the red minus luminance channel standard deviations $\sigma(R-Y)$, and the blue minus luminance channel standard deviation $\sigma(B-Y)$. The following equation, as specified in 6.2.3 of ISO 12232:1998, shall be used.

$$\sigma(i) = \left[\sigma(Y)^2 + 0{,}64\sigma(R-Y)^2 + 0{,}16\sigma(B-Y)^2\right]^{\frac{1}{2}} \qquad (6)$$

The incremental gain (the rate of change in the output level divided by the rate of change in the input density) is determined from the Scanner OECF as follows:

$$g_i = \left(\frac{Y_i - Y(i+1)}{T_i - T(i+1)} + \frac{Y(i-1) - Y_i}{T(i-1) - T_i}\right)\Big/2 \qquad \text{for } i_{\text{min}} < i < i_{\text{max}}$$

$$g(i_{\text{min}}) = \left(\frac{Y_i - Y(i+1)}{T_i - T(i+1)}\right) \qquad (7)$$

$$g(i_{\text{max}}) = \left(\frac{Y(i-1) - Y_i}{T(i-1) - T_i}\right)$$

where

g_i is the incremental gain of patch i;

Y_i is the visually weighted average count level of patch i as given in 7.1;

T_i is the transmission level of patch i as given in 7.4;

i is the number of grey patch with i_{min} as lightest and i_{max} as darkest patch.

8 Presentation of results

8.1 General

The scan settings shall be explicitly stated, including

- make and model;
- sampling frequency (in samples per mm) in the slow and fast scan directions;
- sharpening setting;
- grey scale or RGB scan mode;
- scan speed; and
- brightness, contrast and gamma correction settings.

For settings that are manufacturer-specific, the manufacturer's language shall be used.

8.2 Scanner OECF

The results of the Scanner OECF shall be presented in tabular or graphical form. All logarithmic values shall be base 10. The table heading or figure caption shall indicate the scan settings.

8.2.1 Table presentation

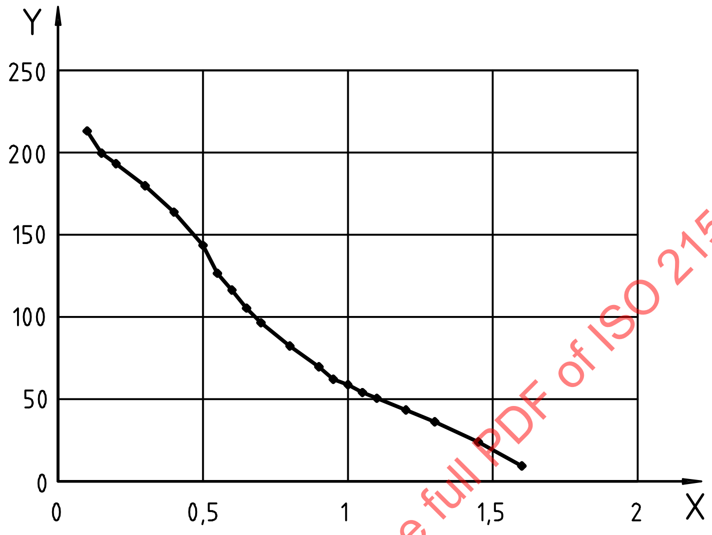
The table shall report the input densities of all the test chart patches and the mean output levels for the luminance channel if the scan mode is grey scale or the calculated luminance as given in 7.1 and if the scan mode is RGB the mean output levels for all three channels.

Table 1 — Scanner OECF
(Scanner X, Model Y, 40 samples per millimetre, no sharpening, line illumination, grey scale scan mode, normal scan speed.)

OECF Patch	Density d	Transmission T	Visually weighted output signal Y	Incremental gain g	Standard deviation σ	Signal to noise ratio S/N(x)
1	0,07	0,85	249,18	3391,79	2,79	1036,47
2	0,07	0,85	248,71	1682,21	3,14	456,63
3	0,08	0,83	249,24	21,49	3,30	5,41
4	0,09	0,81	247,91	898,62	3,39	215,47
5	0,09	0,81	244,75	950,57	3,46	223,02
6	0,10	0,79	241,84	160,14	3,11	40,87
7	0,13	0,74	234,10	132,08	3,32	29,52
8	0,17	0,68	226,39	142,87	4,05	23,84
9	0,22	0,60	214,07	162,03	4,97	19,65
10	0,31	0,49	196,43	179,36	5,10	17,22
11	0,40	0,40	177,88	196,88	4,88	16,08
12	0,51	0,31	160,83	223,53	4,45	15,51
13	0,71	0,19	131,68	274,10	3,56	15,02
14	0,94	0,11	108,22	367,29	3,77	11,19
15	1,21	0,06	84,73	558,37	3,89	8,85
16	1,55	0,03	62,14	937,42	3,59	7,35
17	1,86	0,01	44,88	1480,07	3,00	6,81
18	2,18	0,01	32,21	2431,06	2,45	6,56
19	2,74	0,00	17,36	4361,26	3,13	2,53
20	3,15	0,00	11,12	7700,53	3,46	1,57
21	3,56	0,00	6,89	11124,41	4,23	0,72
22	3,94	0,00	4,88	10952,36	4,63	0,27
23	4,21	0,00	4,38	29454,97	4,52	0,40
24	4,38	0,00	3,39	49473,46	4,47	0,46

8.2.2 Graphical presentation

The graphical presentation shall be a plot of the digital output level, or log of the digital output level, vs. the input densities of all the test chart patches. If the scanning system is a multi-spectral system, the digital output levels for all spectral bands and the luminance channel used for scanner dynamic range calculation shall be plotted (see Figure 2).



Key

X is transmission density

Y is count value

Scanner X, Model Y, 40 samples per millimetre in fast and slow scan directions, no sharpening, grey scale scan mode, normal scan speed.

Figure 2 — Sample Scanner OECF curve for an electronic scanner

8.3 Scanner dynamic range measurements

The results of the dynamic range 7.2 shall be reported as d_r in densities or as contrast value given as:

$$10^{d_r}: 1 \qquad (8)$$

e.g. if d_r = 3 densities the contrast is 1000:1.

The scanner dynamic range for the sample scanner in 8.1 is d_r = 3,6 Densities or approx. 4000:1.

If the Callier Q factor is greater than 1,05 it shall be reported together with the scanner dynamic range.