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Information technology — Office equipment — Test pages and methods for measuring monochrome printer resolution

Technologies de l'information — Équipement de bureau — Diagrammes et méthodes pour mesurer la résolution des imprimantes monochromes

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/IEC JTC1, *Information technology*, Subcommittee SC 28, *Office equipment*.

This first edition cancels and replaces ISO/IEC TS 29112:2012.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The purpose of this document is to provide a process for the objective measurement of print quality characteristics that contribute to perceived resolution in pages printed on paper or similar opaque materials using monochrome electro-photographic printing processes.

This document prescribes the following:

— Definitions of print quality characteristics that contribute to perceived resolution.

— Definitions of conformance methods to qualify a reflection scanner for use as a measuring device.

— A testing procedure based upon:

  a) a well-documented printer and printing environment setup,

  b) well-controlled printing of specified test pages, and

  c) subsequent measurement of print quality characteristics using reflection scans of test pattern elements on the printed test pages.

— Definitions of methods for measuring the contributing print quality characteristics using printed test pattern elements of the specified test pages and analysing the resulting data to derive an assessment of printer resolution.

— Requirements for the report of a printer resolution assessment that define the context of the assessment and describe the results of the assessment.

Printer resolution, a quantification of the ability of a digital printing system to depict fine spatial detail, is a perceptually complex entity with no single, simple, objective measure. Five print quality characteristics that meaningfully contribute to resolution are described in this document. These print quality characteristics are: native addressability, effective addressability, edge blurriness, edge raggedness and the printing system spatial frequency response characteristic (SFR).

— Native or physical addressability refers to the imaging framework in a digital printing process, usually a rectangular grid of printable spots, which enables depiction of fine spatial detail. Native addressability specifies only one facet of the perceived resolution of a printing system. The common unit for native addressability is DPI (dots per inch).

— Effective addressability is a measure of the minimum pitch by which the centre of a printed object (e.g. line segment) can be displaced and evaluates the effects of imaged spot position modulation, size modulation or exposure modulation.

— Edge blurriness provides an optical measure of the geometric transition width of an edge between an unprinted substrate region and a printed solid area region.

— Edge raggedness provides an optical measure of the geometric deviations of a printed edge from a requested straight line.

— The spatial frequency response characteristic (SFR) describes the ability of a linear imaging system to depict fine spatial detail. This is the spatial analogue of frequency response used to characterize sound reproduction. A common synonym of the SFR characteristic is the modulation transfer function (MTF). The ability to depict fine spatial detail is affected by edge blurriness and edge raggedness as well as the spot size and shape of the printer's marking technology and any adjacency effects that can occur in the reproduction of fine detail. Two measurement methods are described that provide estimates of the printing system's spatial frequency response including contributions from edge blurriness, edge raggedness, spot-size, spot shape and adjacency effects.

An essential part of the development of this document was verification that the specified measurement methods correlate well with perceived printer resolution (the ability of a digital printing system to depict fine spatial detail) and that the measurements are reproducible across laboratories and instruments.

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The steps in and results of this process to verify the utility of the measurement methods specified in this document are presented in more detail in Annex F. The applicability of the measurement methods specified in this document could be expanded by undertaking similar verification processes with other printing technologies.

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Information technology — Office equipment — Test pages and methods for measuring monochrome printer resolution

1 Scope

This document defines methods for the objective measurement of the print quality characteristics that contribute to the perceived resolution of reflection mode monochrome printed pages produced by digital electro-photographic printers. The measurement methods of this document are derived from several existing techniques for the assessment of an imaging system's resolution characteristics. Each of these measurement methods is intended for the engineering evaluation of a printing system's perceived resolution and is not intended to be used for purposes of advertising claims.

The methods of this document are applicable only to monochrome prints produced in reflection mode by electro-photographic printing technology. This document is intended for monochrome printers utilizing PostScript®[1)] interpreters capable of accepting PostScript and encapsulated PostScript (EPS) jobs.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 12233, *Photography — Electronic still picture imaging — Resolution and spatial frequency responses*

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

ISO 16067-1, *Photography: Spatial resolution measurements of electronic scanners for photographic images — Part 1: Scanners for reflective media*

ISO/IEC 24790, *Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org

3.1.1
addressability
number of uniquely identifiable printable spot positions per unit distance

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3.1.2
bitmap
two-dimensional rectangular matrix of values representing the *pixels* (3.1.21) in a printed page

3.1.3
cross-track
oriented perpendicular to the direction of print substrate motion (cross-track direction)

3.1.4
cross-track addressability
addressability (3.1.1) of the printer in the direction perpendicular to the motion of the print substrate through the printer

3.1.6
edge blurriness
appearance of being hazy or indistinct in outline, giving a noticeable transition of density from a line element to the background substrate whose transition width is zero for an ideally sharp edge

Note 1 to entry: The measured optical width of the transition region perpendicular to the straight edge boundary between an unprinted substrate area and a solid printed area provides an assessment of edge blurriness.

3.1.7
edge raggedness
appearance of geometric distortion of an edge from its ideal position

Note 1 to entry: Measurement of the geometric deviations from straightness of a contour at a specific reflectance ratio in the edge boundary region between the unprinted substrate area and the solid printed area of a requested straight edge provides an assessment of edge raggedness.

Note 2 to entry: An ideal edge should be absolutely straight along the length of a straight line.

3.1.8
edge transition width
distance between the points of a *normal edge profile* (3.1.19) identified at 70 % of the edge transition reflectance range and 10 % of that reflectance range, the region in which *edge blurriness* (3.1.6) is measured

Note 1 to entry: The edge transition reflectance range is the reflectance difference between the maximum measured reflectance factor, R_{max}, typically of the substrate, and the minimum measured reflectance factor, R_{min}, typically of a region printed at a maximum printing value.

3.1.9
edge spread function
normalized spatial signal distribution in the scanned output of a printing system resulting from imaging a theoretical infinitely sharp edge

Note 1 to entry: In measurement of the edge spread function, the tone-scale of the scanning system is corrected to be linear in reflectance. See ISO 12231.

3.1.10
effective addressability
one over the minimum pitch by which the centre of a printed object can be displaced, with the constraint that the objects compared are of constant dimension in the direction parallel to the centroid position change direction

Note 1 to entry: The effective addressability of a printer can be greater than its native addressability. This higher effective addressability is generally controlled algorithmically within the digital data path processing of the printer and is generally not accessible to a user of the printer.

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3.1.11
human eye modulation response
response of the human visual system to viewed sinusoidal *modulation* (3.1.15) patterns as a function of the spatial frequency of these modulation patterns

3.1.12
in-track
oriented along the direction of print substrate motion

3.1.13
in-track addressability
addressability (3.1.1) of the printer in the direction parallel to the motion of the print substrate through the printer

3.1.14
limiting resolution
spatial frequency at which the *modulation* (3.1.15) of alternating printed high-contrast lines and spaces is 10 % of the zero-frequency spatial frequency response of the printing system

3.1.15
modulation
difference between the maximum and minimum signal levels divided by the sum of these two levels

3.1.16
modulation transfer function
MTF
spatial frequency response
SFR
ratio, as a function of spatial frequency, of the measured *modulation* (3.1.15) response in a print produced by a printing system, to the stimulus modulation presented to that printing system

3.1.17
monochrome
printing using a single colorant, in particular, a single black colorant

3.1.18
native addressability
one over the minimum pitch between adjacent *spots* (3.1.35) that can be independently controlled and produced by the printer

3.1.19
normal edge profile
NEP
reflectance trace across the transition region perpendicular to the boundary of a straight edge between an unprinted substrate area and a solid printed area

Note 1 to entry: For the edge blurriness measurement specified in this document, the transition region is measured between the 10 % and 70 % reflectance levels.

Note 2 to entry: The normal edge profile can be represented as the convolution of an edge spread function and an infinitely sharp edge transition. In turn, for a linear system, the edge spread function is the Fourier transform of the spatial frequency response (or modulation transfer function). For printing systems, which are usually not linear systems, this latter relationship is only approximate.

3.1.20
Nyquist limit
Nyquist frequency
spatial frequency equal to one half the inverse of the sampling spacing for an adjacent pair of sampling points

Note 1 to entry: This can also be expressed as one half of the spatial sampling frequency.

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3.1.21
pixel
smallest addressable element of a digital source image

3.1.22
raster image processor
RIP
component used in a printing system which produces a *bitmap* (3.1.2)

3.1.23
reflectance factor
ratio of the reflected flux as measured to the reflected flux under the same geometrical and spectral conditions for an ideal 100 % diffuse reflecting surface

3.1.24
resolution enhancement technology
control of the printed spot (3.1.36) position to a pitch that is less than the *native addressability* (3.1.18) of the printing system accomplished through local control of one or more spot characteristics

Note 1 to entry: The spot characteristics are spot reflectance (gray-level modulation), size of a spot (size modulation) or local position of a spot (position modulation).

3.1.25
reflectance threshold
R_p
level in the reflectance gradient profile of an edge that is at some specified percentage of the transition from the minimum reflectance factor, R_{min} (3.1.27), to the maximum reflectance factor, R_{max} (3.1.26), as: $R_p = R_{min} + p\%(R_{max} - R_{min})$

3.1.26
R_{max}
maximum measured *reflectance factor* (3.1.23), typically of the substrate

3.1.27
R_{min}
minimum measured *reflectance factor* (3.1.23), typically of a region printed at a maximum printing value

3.1.28
R_{10}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 10 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{10} = R_{min} + 10\ \% (R_{max} - R_{min})$

3.1.29
R_{25}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 25 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{25} = R_{min} + 25\ \% (R_{max} - R_{min})$

3.1.30
R_{40}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 40 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{40} = R_{min} + 40\ \% (R_{max} - R_{min})$

3.1.31
R_{70}
contour of points of an image element where the edge gradient profiles cross a reflectance level that is 70 % of the transition from the substrate reflectance factor, R_{max} (3.1.26), to the minimum image reflectance factor, R_{min} (3.1.27): $R_{70} = R_{min} + 70\ \% (R_{max} - R_{min})$

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3.1.32
sampling efficiency
fraction of the *Nyquist frequency* (3.1.20) corresponding to the frequency where the *spatial frequency response* characteristic (3.1.16) has dropped to 10% of its zero-frequency value

3.1.33
sampling frequency
spatial frequency of adjacent sampling points where sampling points are conventionally oriented along the direction of print substrate motion, the *in-track direction* (3.1.12), or perpendicular to the direction of print substrate motion, the *cross-track direction* (3.1.3)

3.1.34
scanner tone-scale calibration
opto-electronic conversion function
OECF
digital signal conversion that adjusts the relationship between the reflectance values of large imaged areas and the corresponding digital code values

Note 1 to entry: Code values are the reflection scanner response to a scanned reflection stimulus, e.g. *test elements* (3.1.37). Scanner tone-scale calibration can be used to adjust the relationship between scanned pixel values and large area reflectance to an aim relationship, e.g. scanned pixel values that have a linear relationship with measured print reflectance.

3.1.35
spot
smallest mark that can be placed under user control at a desired position on a printed page, independently from all other adjacent marks

3.1.36
tangential edge profile
TEP
array of geometric positions of a contour at a specific *reflectance threshold* (3.1.25) along the printed rendition of a perfectly straight edge boundary between an unprinted substrate area and a solid printed area

Note 1 to entry: For the edge raggedness measure specified in this document, the contour is taken at a 40 % reflectance level.

3.1.37
test element
elemental part of a test pattern used to assess a particular aspect of a printing system

3.1.38
test page
arrangement in a printable page of *test elements* (3.1.37) or *test patterns* (3.1.39) designed to test one or more particular aspects of a printing system

3.1.39
test pattern
specified arrangement of printable objects [*test elements* (3.1.37)] designed to test a particular aspect of a printing system

3.1.40
test suite
set of printable *test pages* (3.1.38) designed to test a number of different aspects of a printing system

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3.2 Abbreviations

Abbreviation	Term
cy/mm	cycles per millimetre NOTE 1 This is the unit for specifying spatial frequency.
dpi (DPI)	dots per inch NOTE 2 This is the common unit for printing system native addressability.
lp/mm	line pairs per millimetre NOTE 3 This is the unit for specifying resolution in terms of the number of equal width black and white line pairs per millimetre that can be resolved according to a criterion such as limiting resolution (3.1.14).
MTF	modulation transfer function (3.1.16)
NEP	normal edge profile (3.1.19)
ppi (PPI)	pixels per inch NOTE 4 This refers to the physical addressability of a digital scanning system.
RIP	raster image processor (3.1.22)
TEP	tangential edge profile (3.1.36)
SFR	spatial frequency response (3.1.16)
spi (SPI)	spots per inch NOTE 5 The printing system native addressability can be expressed in spots per inch. This is an alternative to the more common term DPI.

4 Print resolution characteristics — Methods for measurement and analysis

4.1 Conformance requirements

4.1.1 General

The print resolution characteristic measurement methods defined in this document rely on the objective evaluation of digital images scanned from printed test pages. The single exception to this is the method for native addressability which relies on the visual evaluation of a printed test page.

The test pages, the printing process employed to print test page samples for evaluation, the characteristics of the scanner employed for objective evaluation and the measurement methods utilized shall all meet conformance requirements to ensure that the reported measurements are valid.

4.1.2 Test page conformance

The test pages used with the measurement methods specified in this document are available from http://standards.iso.org/iso-iec/29112/ed-1/en in the ZIP file named Test pages.zip.

— The latest collection of these test pages shall always be used.

— The test page name and version used in printer resolution assessment shall be recorded in the test report.

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