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

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

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Foreword

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The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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ISO/IEC TS 29112 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 28, *Office equipment*.

Introduction

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

This Technical Specification prescribes the following:

- Definitions of the 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 well-documented printer and printing environment setup; well-controlled printing of specified test charts; and subsequent measurement of relevant print quality characteristics using test pattern elements on the printed test charts.
- Definitions of methods for measuring the contributing print quality characteristics using test patterns elements of the printed test charts, analyzing the resulting data, and deriving 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 Technical Specification. These print quality characteristics are: native addressability, effective addressability, edge blurriness, edge raggedness, and the printing system modulation transfer function (MTF).

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.

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 modulation transfer function (MTF) describes the ability of a linear imaging system to depict fine spatial detail. The ability to depict fine spatial detail is affected by edge blurriness as well as the spot size of the printer's marking technology and any adjacency effects that may occur in the reproduction of fine detail. Two measurement methods are described that provide estimates of the printing system's modulation transfer function including contributions from edge blurriness, spot-size and adjacency effects.

Verification of the measurement methods specified in this Technical Specification is underway.

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

1 Scope

This Technical Specification 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 Technical Specification 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 should not be used for purposes of advertising claims.

The methods of this Technical Specification are applicable only to monochrome prints produced in reflection mode by electro-photographic printing technology. The current version of this Technical Specification is intended for monochrome printers utilizing Postscript interpreters capable of accepting Postscript and encapsulated Postscript (EPS) jobs.

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 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 21550, *Photography — Electronic scanners for photographic images — Dynamic range measurements*

3 Terms and definitions

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

3.1
addressability
number of uniquely identifiable printable spot positions per unit distance

3.2
addressability, cross-track
addressability of the printer in the direction perpendicular to the motion of the print substrate through the printer

3.3
addressability, effective
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: The effective addressability of a printer may 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.

3.4
addressability, in-track
addressability of the printer in the direction parallel to the motion of the print substrate through the printer

3.5
addressability, native
one over the minimum pitch between adjacent spots that can be independently controlled and produced by the printer

Note: Native addressability is commonly measured in dots per inch (dpi).

3.6
cycles per millimetre (cy/mm)
unit used for specifying spatial frequency

3.7
CMT Acutance (CMTA or Cascaded Modulation Transfer Acutance)
area under the system modulation transfer curve formed by multiplying (cascading) the individual component modulation transfer functions and the human eye modulation response characteristic:

$MT_{system}(\nu) = MT_1(\nu) \times MT_2(\nu) \ldots MT_i(\nu)$, where one of the MTF functions is the modulation response characteristic of the human eye, and ν denotes spatial frequency (cy/mm)

Note: See reference 1 (Bibliography) for further detail.

3.8
cross-track
oriented perpendicular to the direction of print substrate motion (cross-track direction)

3.9
edge blurriness
slowly changing transition between an unprinted substrate area and a solid printed area

Note: 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.

3.10
edge raggedness
small deviations of an edge from expected straight line

Note: 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.

3.11
edge transition width
distance between the points of a normal edge profile identified at 70% of the edge transition reflectance range and 10% of that reflectance range, the region in which edge blurriness is measured

Note: 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.

3.12
edge spread function
normalized spatial signal distribution in the scanned output of a printing system resulting from imaging a theoretical infinitely sharp edge

Note: In measurement of the edge spread function, the tone-scale of the scanning system shall be corrected to be linear in reflectance. See ISO 12231:2005.

3.13
human eye modulation response characteristic
the response of the human visual system to viewed sinusoidal modulation patterns as a function of the spatial frequency of these modulation patterns

3.14
In-track
oriented along the direction of print substrate motion (in-track direction)

3.15
limiting resolution
spatial frequency at which the modulation of adjacent printed high-contrast lines and spaces is 10% of the DC modulation capability of the printing system

3.16
line pairs per millimetre (lp/mm)
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

3.17
modulation
difference between the maximum and minimum signal levels divided by the sum of these two levels

3.18
modulation transfer function
MTF
ratio, as a function of spatial frequency, of the measured modulation response in a print produced by a printing system, to the stimulus modulation presented to that printing system

3.19
monochrome
printing using a single colorant, in particular, a single black colorant

3.20
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: The normal edge profile can be represented as the convolution of an edge spread function and an infinitely sharp edge transition. In turn, the edge spread function is the Fourier transform of the modulation transfer function of the linear system represented by the printing system.

3.21
nyquist limit
spatial frequency equal to one half the inverse of the sampling spacing for an adjacent pair of sampling points, alternatively, one half of the spatial sampling frequency

3.22
pixel
smallest addressable element of a digital source image

3.23
raster image processor
RIP
component used in a printing system which produces a bitmap

3.24
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

3.25
resolution enhancement technology
control of the printed spot position to a pitch that is less than the native addressability of the printing system accomplished through local control of one or more spot characteristics, which are spot reflectance (gray-level modulation), size of a spot (size modulation), or local position of a spot (position modulation)

3.26
Reflectance threshold
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}) to the maximum reflectance factor (R_{max}) as: $R_p = R_{min} + p\%(R_{\max} - R_{min})$

3.27
R_{max}
maximum measured reflectance factor, typically of the substrate

3.28
R_{min}
minimum measured reflectance factor, typically of a region printed at a maximum printing value

3.29
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}) to the minimum image reflectance factor (R_{min}): $R_{10} = R_{min}+10\% (R_{max} - R_{min})$

3.30
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}) to the minimum image reflectance factor (R_{min}): $R_{25} = R_{min}+25\% (R_{max} - R_{min})$

3.31
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}) to the minimum image reflectance factor (R_{min}): $R_{40} = R_{min}+40\% (R_{max} - R_{min})$

3.32
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}) to the minimum image reflectance factor (R_{min}): $R_{70} = R_{min}+70\%(R_{max} - R_{min})$

3.33
sampling interval
physical distance between a pair of adjacent sampling points, where adjacent sampling points are oriented along the direction of print substrate motion (in-track direction), or perpendicular to the direction of print substrate motion (cross-track direction)

3.34
sampling frequency
spatial frequency, measured in units of cy/mm, of adjacent sampling points where sampling points are oriented along the direction of print substrate motion (in-track direction), or perpendicular to the direction of print substrate motion (cross-track direction)

3.35
spatial frequency response
SFR
measured amplitude response of an imaging system as a function of spatial frequency

3.36
spot
smallest mark that can be placed under user control at a desired position on a printed page, independently from all other adjacent marks

3.37
tangential edge profile
TEP
reflectance trace of a contour at a specific reflectance threshold along the printed rendition of a perfectly straight edge boundary between an unprinted substrate area and a solid printed area

3.38
test chart
arrangement of test patterns designed to test particular aspects of a printing system

3.39
test pattern
specified arrangement of printable objects (test elements) designed to test particular aspects of a printing system

3.40
tone-scale correction (scanner)
digital signal conversion that adjusts the relationship between the reflectance values of large imaged areas and the corresponding digital code values

Note: Code values are the reflection scanner response to a scanned reflection stimulus (e.g. test chart) tone-scale correction may 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.

4 Print resolution characteristics – methods for measurement and analysis

4.1 Compliance requirements

The print resolution characteristic measurement methods defined in this Technical Specification rely on the objective evaluation of scanned images produced by printing test charts. The single exception to this is the method for native addressability which relies on the visual evaluation of a printed test chart.

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

4.1.1 Test chart compliance

The test charts for this technical specification are specified in Annex A (normative), Test charts. These test charts are included in the distribution media of this Technical Specification and are also available from the ISO web site at http://standards.iso.org/ittf/PubliclyAvailableStandards/SC28_Test_Pages. The ZIP file TS29112_TestCharts contains the current set of Test Charts for use with this Technical Specification.

The name and version of each test chart used in printer resolution assessment shall be recorded in the test report.

These test charts are provided in Encapsulated Postscript (EPS) format. With Postscript compatible printers, this format permits matching the test chart content to the addressability characteristics of the printer's raster image processor (RIP).

4.1.2 Printing process compliance

The printing process specified in this Technical Specification avoids the re-interpretations of test chart content provided by many imaging or graphics applications. The assessment of printer resolution characteristics is thus made independent of application features and is therefore representative of the inherent capability of the printer.

The procedure specified in Annex B (normative), Printing method, shall be used to submit the test charts for this printer resolution assessment to the printer being assessed. The name of the printer, the settings of the low-level printing application used to submit the test charts, and a specification of the printing application, as specified in clause 6.2 and in Annex B, shall be recorded in the test report.

One or more pages shall be printed prior to running a test to ensure that the printer is properly warmed up.

4.1.3 Scanner characteristics compliance

Many of the measurement methods utilized in this Technical Specification employ a reflection scanner as an analytic measurement device. These measurements will provide an accurate assessment of printer resolution characteristics only if the scanner capabilities are sufficiently high that the scanner itself does not limit the assessment and if the scanner control application is configured to deliver accurate and repeatable imagery. Annex C, (Normative) Scanner conformance specifies the conditions that shall be met by a reflection scanner and its scanner control application for qualification as a measurement device in the measurement methods of this Technical Specification.

4.1.4 Measurement method compliance

The procedures specified in Annex D, (normative) Measurement method conformance, shall be used to qualify the measurement method implementations used with this Technical Specification.

Failure to use a compliant implementation of the measurement methods defined in this Technical Specification shall invalidate any test results obtained using that implementation. The name of the implementation and the name of the implementer, or implementing organization, for each measurement method used in printer resolution assessment shall be recorded in the test report.

4.2 Native addressability

Native addressability, often referred to as physical addressability, or simply addressability, may differ in the in-track direction and in the cross-track direction of the printing process.

A Postscript printer RIP will provide a value for the printer addressability when queried. When printed, the test chart for evaluating native addressability automatically obtains addressability values from the RIP.

Note: In most cases, evaluation of the printed target will simply verify the native addressability reported by the printer's RIP.

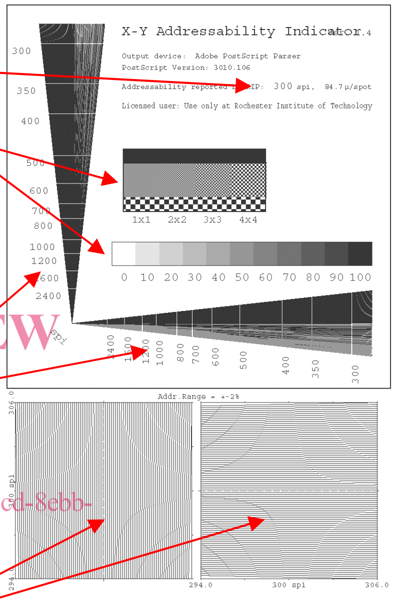
4.2.1 Method for measuring native addressability

Unlike the other measurement methods specified in this Technical Specification, the native addressability of a printing system is determined by visual evaluation. This visual evaluation procedure may be iterative.

Table 1, Native Addressability

Test chart:	ADDIN180_TestChart.eps (per Annex A (Normative))
Test chart editing:	(Optional) To over-ride addressability values reported by the RIP
Printing method:	According to the procedure specified in Annex B (Normative)
Analysis method:	Visual evaluation

Print the test chart file ADDIN180_TestChart.eps according to the method specified in Annex B (Normative), Printing method. The native addressability test chart contains three sets of elements as shown in Figure 1.



Printing status and configuration check elements:

The native addressability reported by the RIP is shown here. Two check elements are visually evaluated to verify that the printing configuration allows correct assessment of the native addressability test chart. All four checkerboard patterns and all eleven levels of the tone scale ramp should be evident and distinct. If not evident and distinct, a workflow or RIP configuration error is indicated (improper resolution, high-contrast tone-scale, binary rendition, etc.) which must be remedied before utilizing this target.

Coarse native addressability assessment scales:

Cross-track and in-track scales are provided to estimate the approximate native addressability of a printing system. Moire patterns in these elements disappear at the printer resolution. Visual assessment of these positions and the adjacent resolution scales provides an indication of the approximate native addressability.

Fine native addressability assessment scales:

Cross-track and in-track scales are provided to estimate the native addressability of a printing system to much higher precision.

Visual assessment of the position where the Moire patterns in these elements disappear provides a very precise and accurate measure of the native addressability of the printing system under assessment.

Figure 1. Native addressability test chart

The ADDIN180_TestChart.eps file queries the addressability characteristics of the printer's raster image processor (RIP) and adjusts the test chart content to exactly match these reported addressability characteristics.

Note: In most cases, evaluation of a printed page of the ADDIN180_TestChart.eps file will simply verify the native addressability that is reported by the printer RIP and displayed in the upper right corner area of the target. This reported value is correct if both of the following conditions are met:

1) The native addressability indicated by examination of the coarse native addressability assessment scales is within two percent of the native addressability reported by the RIP.
2) The native addressability indicated by examination of the fine native addressability assessment scales is within 0,2 pixels per centimetre (or 0,5 pixels per inch) of the native addressability reported by the RIP.

If the in-track and cross-track native addressability indicated by examination of the in-track and cross-track coarse and fine assessment scales are both within two percent of the value reported by the printer's RIP, then the fine assessment scales are in range and the native addressability values obtained by visual evaluation of both coarse and fine assessment scales should be considered as the true in-track and cross-track native addressability of the printing system.