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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.

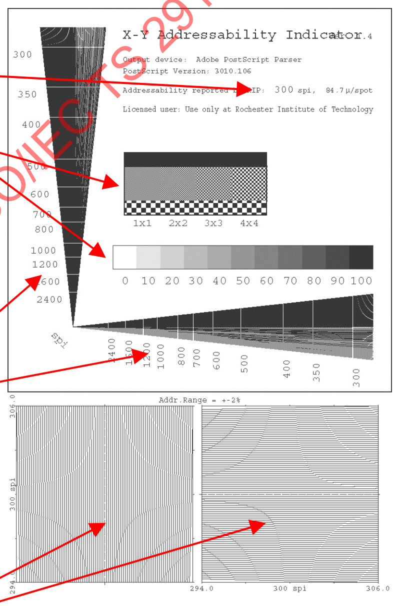


Figure 1. Native addressability test chart

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.

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.

If the visual inspection results differ from the value reported by the RIP by more than two percent, then the fine assessment scales will be out of range and will not provide an unambiguous measure of the printing system's true native addressability. Further investigation is required and consists of three steps:

1) Open a renamed copy of the ADDIN180_TestChart.eps file in a text editor and edit the `/SetDPI` line in this Postscript text file that is used to over-ride use of the RIP queried values for in-track and cross-track native addressability values to reflect the values determined by visual inspection of the original sample print of the native addressability target. The `/SetDPI` line of the Postscript text file is illustrated below.

```
/SetDPI 0 def     % You can set the DPI that the program will adapt to. When
                  % set to zero, this will be done automatically, by checking the
                  % number of addressability steps per inch of the output device.
                  % Zero should be the normal setting. But, if it is necessary to
                  % adjust the center spi to show in the large squares (because
                  % the automatic adjustment is off center) then it is possible to
                  % set it here.
```

2) Print and evaluate the edited and saved test chart. When the coarse in-track and cross-track native addressability obtained by evaluation of the most recently printed test chart are each within two percent of the addressability values entered through the text editor into the defining fields of the test chart file, then the fine native addressability scales are in range and visual evaluation can provide a measurement of the true native addressability of the printing system that is accurate to within 0.2 pixels per centimetre (or 0.5 pixels per inch). This is the tolerance required for evaluation of printer native addressability.

3) If visual inspection of the printed test chart still indicates an addressability outside the two percent range of the fine native addressability scales, continue to refine the edited native addressability setting in the Postscript file in order to evaluate the printing system native addressability by repeating steps 1 – 3.

   Note: Usually one iteration of this process will be sufficient to provide an accurate estimate of the native addressability of a printing system.

The values obtained through this evaluation process for in-track native addressability and for cross-track native addressability shall be entered into the printer resolution test report as described in clause 6.3.

4.3 Effective addressability

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. The effective addressability of a printer may differ in the in-track direction and in the cross-track direction.

4.3.1 Method for measuring effective addressability

Create a renamed copy of the files EffAddr03_IT.eps and EffAddr03_XT.eps. Open this copy in a text editor and edit the line that specifies the native addressability of the printer to be tested.

Table 2, Effective Addressability

Test chart:	EffAddr03_IT.eps (per Annex A (Normative)) EffAddr03_XT.eps (per Annex A (Normative))
Test chart editing:	(Required) To specify addressability
Printing method:	According to the procedure specified in Annex B (Normative)
Scanner conformance:	According to the procedure specified in Annex C (Normative)
Measurement conformance:	According to the procedure specified in Annex D (Normative)
Reference analysis method:	EffAddr_v03

Print the edited and saved test chart files according to the method specified in Annex B (Normative), Printing method. The effective addressability test chart shall be edited, saved, and printed separately to evaluate in-track effective addressability and to evaluate cross-track effective addressability.

The set of sample prints created by printing the edited and saved test chart files shall be scanned at a resolution equal to or greater than the native addressability of the printing system being assessed or at a scanning resolution that is at least half of the effective addressability of the printing system being assessed, whichever is greater. Measurement of effective addressability may require re-scanning at a higher scan resolution. (The test chart and measurement procedure are designed to allow the effective addressability to exceed the scan resolution.) The scanner characteristics at this resolution shall conform to the requirements specified in Annex C (normative), Scanner conformance, to provide valid lossless image files for analysis. An illustrative region of a printed EffAddr03_IT.eps file is illustrated in Figure 2.

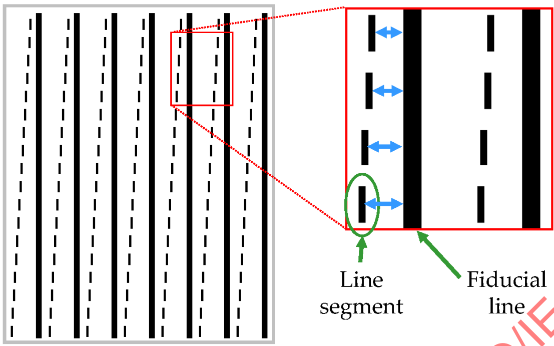


Figure 2. Effective Addressability test chart.

Analyze the scanned image files using the effective addressability measurement method defined in this Technical Specification or a conforming implementation of this measurement method (Annex D.1, Effective addressability measurement method). If the analysis shows two peaks, the effective addressability reported by the analysis is obtained from the position of the second peak. If the analysis shows only a single peak, the effective addressability test charts must be renamed, edited, saved, reprinted and reanalyzed until the analysis shows two peaks. The process to be followed if the analysis shows only a single peak is as follows:

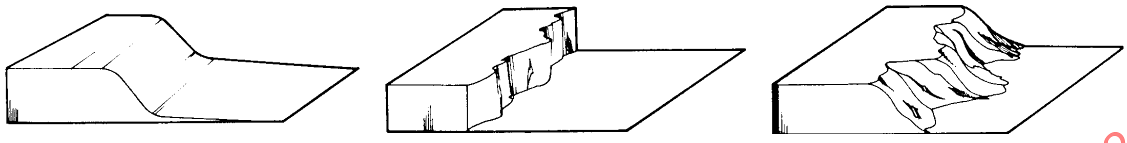
1. Open a re-named copy of the effective addressability test chart and edit the Postscript line specifying the target resolution. Increase the target resolution multiplier by a factor of two from its previous value (the initial value of the target resolution multiplier in any evaluation must be 2.) The effective addressability of the printing system being assessed is the target resolution times the target resolution multiplier.
2. Save and print the edited copy of the effective addressability test chart according to the method specified in Annex B (Normative), Printing method.
3. These newly printed samples shall be scanned at a resolution equal to or greater than the native addressability of the printing system being assessed or at a scanning resolution that is at least half of the effective addressability of the printing system being assessed, whichever is greater. The scanner characteristics at this resolution shall conform to the requirements specified in Annex C (normative), Scanner conformance, to provide valid lossless image files for analysis.
4. Analyze the scanned image files using the effective addressability measurement method defined in this Technical Specification or a conforming implementation of this measurement method (Annex D.1, Effective addressability measurement method). If the analysis shows two peaks, the effective addressability reported by the analysis is obtained from the position of the second peak. If the analysis shows only a single peak, the process outlined in these steps 1 – 4 must be repeated until two peaks are identified.

The result reported by this measurement method provides a measurement of the effective addressability value of the printer for the selected test chart orientation. In-track effective addressability and cross-track effective addressability are measured separately based on scans of the printed test chart sets created for each of these two orientations. The values obtained for both in-track and for cross-track effective addressability shall be entered into the printer resolution test report as specified in clause 6.3.

4.4 Edge blurriness and edge raggedness

Two characteristics of straight edges are of particular importance in characterizing a printing system:

The normal edge profile (NEP) illustrates how rapidly a transition is made perpendicular to a straight edge. The width of this transition is directly related to the perceived edge blurriness of a printing system. The tangential edge profile (TEP) illustrates how much a straight printed edge deviates from its requested straight line behaviour. The magnitude of the deviations from straight line behaviour is directly related to the perceived edge raggedness of a printing system. These two edge characteristics are illustrated in figure 3.



a. NEP b. TEP c. Both NEP & TEP

Figure 3. Edge blurriness and edge raggedness

4.4.1 Edge blurriness

The measured width of the transition region perpendicular to a straight edge between a solid printed area and a bare substrate area correlates well with the perceived blurriness of a printing system. A smaller transition width correlates with smaller perceived edge blurriness (i.e. greater perceived edge sharpness). Edge blurriness is a characteristic of the normal edge profile (NEP) of a printed edge.

The blurriness of a printed edge is evaluated across the transition region between an unprinted substrate area, with a measured reflectance factor R_{max}, and a printed solid area, with a measured reflectance factor R_{min}. The region of interest (ROI) used in the evaluation of edge blurriness shall extend at least 5mm along the printed edge and at least 2mm perpendicular to the printed edge, extending at least 1mm into the unprinted area and 1mm into the printed area. The scanned image of this ROI, corrected by an OECF LUT to provide a reflectance measure, is analyzed to determine the constant reflectance factor contours within the transition region at reflectance threshold values of 70%, and 10% (R_{70}, and R_{10} contours).

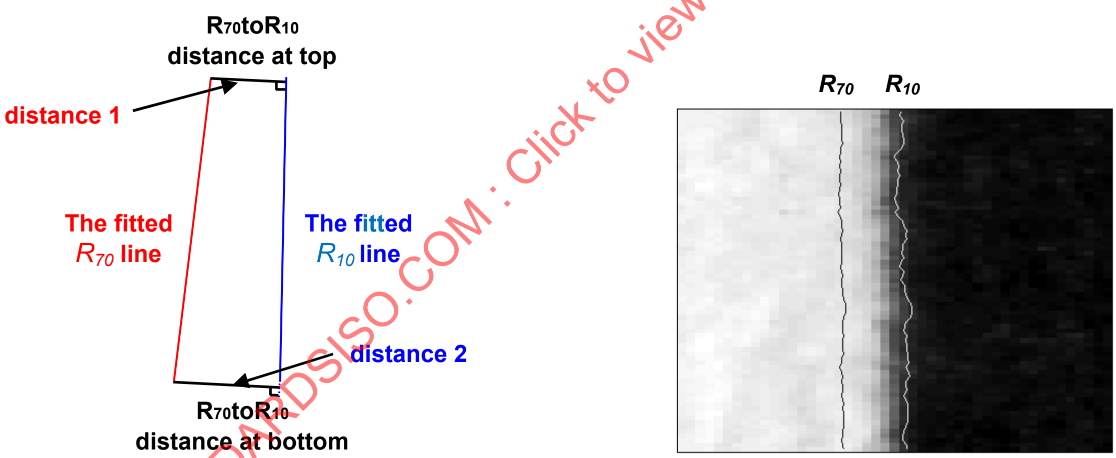


Figure 4. Calculation of the average distance between the R_{70} and R_{10} contours, DIS_{70-10}

The R_{70}, and R_{10} contours are then each fitted to a straight line. Since the lines fitted to the R_{70} and R_{10} contours may not be parallel, the average distance between the R_{70} and R_{10} contours, DIS_{70-10}, is calculated by averaging the two distances at the ends of the fitted line segments, as described in figure 4 and the following equation.

$$DIS_{70-10} = (distance\ 1 + distance\ 2) / 2 \quad \text{Equation 1}$$

The final edge blurriness value is the average distance between the two fitted lines, $DIS_{70\text{-}10}$, weighted by the square root of the average density of the printed solid area region (a unit-less weighting factor).

$$\text{Edge Blurriness} = DIS_{70\text{-}10} \;/\; \sqrt{D_{avg}} \qquad \text{Equation 2}$$

The printed solid area density is evaluated within the 25% reflectance contour (R_{25}) of the printed edge. Edge blurriness is measured using the edge transitions along the sides of the objects illustrated in figure 5.

4.4.2 Edge raggedness

Edge raggedness is a measure of the deviations of a printed straight edge from its expected straight line behaviour. dge raggedness is a characteristic of the tangential edge profile (TEP) of a printed edge.

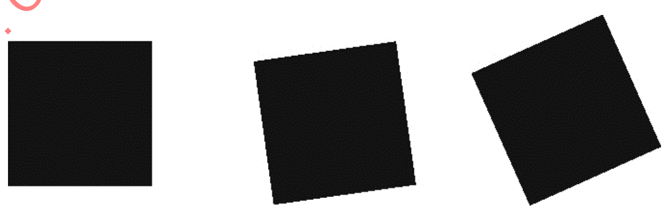
The raggedness of a printed edge is evaluated within the transition region between an unprinted substrate area, with a measured reflectance factor R_{max}, and a printed solid area, with a measured reflectance factor R_{min}. The region of interest (ROI) used in the evaluation of edge raggedness shall extend at least 5mm along the printed edge and at least 2mm perpendicular to the printed edge, extending at least 1mm into the unprinted area and 1mm into the printed area. The scanned image of this ROI, corrected by an OECF LUT to provide a reflectance measure, is analyzed to determine the constant reflectance factor contours within the transition region at a reflectance factor of 40% (R_{40} contour).

$$EdgeRaggedness = \frac{1}{n}\sum_{j=1}^{n}\sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(\text{residuals from a line})^2} \qquad \text{Equation 3}$$

The edge raggedness measure is the standard deviation of the distances between the R_{40} contour and a straight line fitted through the R_{40} contour.

4.4.3 Method for measuring edge blurriness and edge raggedness

Print the test chart file EdgeMetric_v8_TestChart.eps according to Annex B (normative), Printing process. A printed version of this file is illustrated in figure 5, and contains elements used to estimate the edge characteristics of a printer.



0° orientation 8° orientation 24° orientation

Figure 5. Edge characteristics test chart.

Table 3, Edge Blurriness and Edge Raggedness

Test chart:	EdgeMetric_v8_TestChart.eps (per Annex A (Normative))
Printing method:	According to the procedure specified in Annex B (Normative)
Scanner conformance:	According to the procedure specified in Annex C (Normative)
Measurement conformance:	According to the procedure specified in Annex D (Normative)
Reference analysis method:	aboutedge

The set of sample prints created by printing the test chart file shall be scanned at a resolution at least twice the native addressability of the printing system being assessed. The scanner characteristics at this resolution shall conform to the requirements specified in Annex C (normative), Scanner conformance, to provide valid lossless image files for analysis.

Select one or more of the angled elements in the scanned image files for separate, independent analysis using the blurriness and raggedness measurement methods defined in this Technical Specification or a conforming implementation of these measurement methods (Annex D.2, Blurriness measurement method and Annex D.3 Raggedness measurement method). The results reported by these measurement methods provide measurements of the blurriness and raggedness of the printer for the selected test chart orientation.

The values reported for edge blurriness and for edge raggedness shall be entered into the printer resolution test report as specified in clause 6.3.

4.5 Detail carrying capability

The modulation transfer function provides an effective method of describing the capability of a printing system to depict detail as a function of spatial frequency. For this Technical Specification, two methods for estimating complementary aspects of detail rendition capability are employed.

4.5.1 Printer MTF estimation from edge characteristics

Slanted-edge SFR (spatial frequency response) analysis of printed edge transition characteristics contributes a measure of the printer's modulation transfer function from the Fourier transform of the edge spread function. This estimate of the printer MTF characteristic reflects the contribution of edge sharpness to the perceived resolution of a printing system.

The EdgeMetric_v8_TestChart.eps test chart, illustrated in figure 5, contains objects that can provide an estimate of the printer MTF characteristic based on the slanted-edge SFR method (Annex D.4, Slanted-edge SFR measurement method).

MTF estimates may be made using in-track, cross-track or slanted edges. hese estimates of the printer MTF characteristic reflect the contribution of edge sharpness to the perceived resolution of a printing system. A choice is available to select between three sets of edges provided in the EdgeMetric_v8_TestChart.eps test chart: 0° and 90° in-track and cross-track edges, 8° and 82° slanted edges, and 24° and 66° slanted edges.

4.5.2 Method for measuring printer MTF from edge characteristics

Print the test chart file EdgeMetric_v8_TestChart.eps according to Annex B (normative), Printing process. A printed version of this file is illustrated in figure 5, and contains elements used to provide an estimate of a printer's MTF characteristic.

Table 4, MTF from edge characteristics

Test chart:	EdgeMetric_v8_TestChart.eps (per Annex A (Normative))
Printing method:	According to the procedure specified in Annex B (Normative)
Scanner conformance:	According to the procedure specified in Annex C (Normative)
Measurement conformance:	According to the procedure specified in Annex D (Normative)
Reference analysis method:	SlantedEdgeSFR

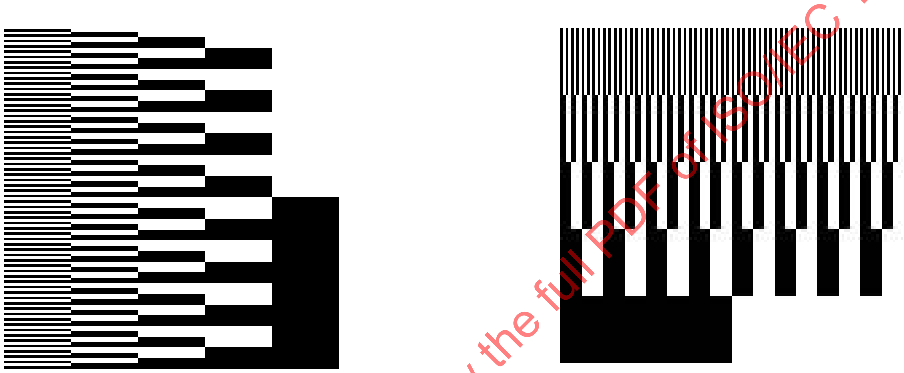
The set of sample prints created by printing the test chart file shall be scanned at a resolution at least twice the native addressability of the printing system being assessed. The scanner characteristics at this resolution shall conform to the requirements specified in Annex C (normative), Scanner conformance, to provide valid lossless image files for analysis.

Analyze the scanned image files using the slanted-edge SFR measurement method defined in this Technical Specification or a conforming implementation of these measurement method (Annex D.4, Slanted-edge SFR measurement method). The results reported by this measurement method provide measurements of the MTF characteristic of the printer based on edge characteristics for the selected test chart orientation.

From the printer MTF characteristic estimates provided by the slanted-edge SFR method, the spatial frequency at 50% modulation provides an estimate of the perceived sharpness of edge detail, and the spatial frequency at 10% modulation provides an estimate of the limiting resolution of edge detail. The cascaded modulation transfer acutance, CMTA[1], based on a weighting of the printing system MTF by the modulation response function of the human eye, provides an overall figure of merit for printing system sharpness. These measured characteristics shall be entered into the printer resolution test report as described in clause 6.3.

4.5.3 Printer MTF estimation from 1-D repeating patterns

Patterns that repeat at a variety of spatial frequencies provide a basis for estimating the printer MTF characteristic that is much more sensitive to spot size, spot shape and adjacency effects than a measurement based purely on edge characteristics. Fourier analysis of a repeating one-dimensional square-wave pattern provides a printer MTF characteristic estimate that reflects the contributions of spot size, spot shape, and adjacency effects to the perceived resolution of a printing system.



0^{o} orientation $\qquad$ 90^{o} orientation

Figure 6. Line characteristics test chart.

The line_characteristics.eps test chart, illustrated in Figure 6, is utilized in the estimation of the printer MTF characteristic from 1-D square-wave patterns repeated both along and perpendicular to the direction of substrate motion (in-track and cross-track orientation). Analysis of the printed one-dimensional square-wave patterns provide odd harmonic amplitudes which, in comparison with the expected amplitudes of an ideal square wave's harmonics, probe the modulation transfer function of the printer at many different spatial frequencies. MTF estimates are provided for in-track and cross-track square-wave patterns. These estimates of the printer MTF characteristic reflect the contributions of edge sharpness as well as spot size, spot shape and adjacency effects to the perceived resolution of a printing system.

4.5.4 Method for measuring printer MTF from 1-D repeating pattern characteristics

Print the test chart file SqWv_MTF30.eps according to Annex B (normative), Printing process. A printed version of this file is illustrated in Figure 6, and contains elements used to provide an estimate of a printer's MTF characteristic.

Table 5, MTF from line characteristics

Test chart:	SqWv_MTF30.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)
Scanner conformance:	According to the procedure specified in Annex C (Normative)
Measurement conformance:	According to the procedure specified in Annex D (Normative)
Reference analysis method:	SqWv_MTF

Scan the set of sample prints created by printing the test chart file at a resolution at least twice the native addressability of the printing system being assessed. The scanner characteristics at this resolution shall conform to the requirements specified in Annex C (normative), Scanner conformance, to provide valid lossless image files for analysis.

Analyze the scanned image files using the square-wave MTF measurement method defined in this Technical Specification or a conforming implementation of these measurement method (Annex D.5, Square-wave MTF measurement method). The results reported by this measurement method provide measurements of the MTF characteristic of the printer based on line characteristics for the selected test chart orientation.

From the printer MTF characteristic estimates provided by the slanted-edge SFR method, the spatial frequency at 50% modulation provides an estimate of the perceived sharpness of repeated detail, and the spatial frequency at 10% modulation provides an estimate of the limiting resolution of repeated detail. The cascaded modulation transfer acutance, CMTA[1], based on a weighting of the printing system MTF by the modulation response function of the human eye, provides an overall figure of merit for printing system sharpness. These measured characteristics shall be entered into the printer resolution test report as described in clause 6.3.

5 Test Set-up, Configurations, and Procedure

5.1 Printer set-up and configuration

The printer shall be set up on a level surface according to the installation guide provided by the printer manufacturer. The most recent software (printer driver, etc.) available from the manufacturer shall be used. Check the manufacturer's web-site for the most recent printer driver that is compatible with the computer operating system that will be used for testing. The printer driver version shall be documented in the test report.

Printer maintenance shall be performed according to the printer manufacturer's User's Manual. All printing device consumables and operating components shall be those specified as acceptable for use by the manufacturer (or otherwise noted). Prior to the start of the test, the total number of pages printed by the printer, the total number of pages printed with each consumable, and the total number of pages printed with each customer replaceable operating component, shall be documented in the test report.

The operating configuration in which a printing system is assessed is as important as the measurement. A particularly important operating configuration is the manufacturer's default configuration. This configuration provides an assessment representative of the majority of a printer's usage. Many manufacturers also define a 'best practice' configuration for achieving optimal print quality. This configuration may utilize specialty substrates or operate more slowly than the default configuration, but an assessment of this configuration is apt to evaluate the optimized capability of a printing system. The printer configuration used in testing shall be documented in the test report.

To assure that the test charts utilized in an assessment of printer resolution are printed correctly, no page size modifiers such as 'Fit to Page' shall be used and font substitution shall be turned off. The test charts shall be printed using the fonts embedded in the file and shall be rendered on the page in a size corresponding to the dimensions specified in the test chart description. Page placement modifiers such as page centering can be used to place the image properly on the page.

5.2 Printer testing environment

The test environment, including temperature and humidity, shall be within the ranges recommended by the manufacturer for operating the printer. If no recommendation is available, the following ranges shall apply:
Temperature: 18 °C to 25 °C
Relative humidity: 30% to 70%
The printer, all supplies, consumables, etc. shall be acclimated to the test environment for a minimum of 24 hours.

The printer shall be connected to a supply of power that is within the manufacturer specified operating voltage and operating frequency range.

The temperature and relative humidity at the beginning and at the end of the test shall be documented in the test report.

5.3 Substrate

The substrate used in printer resolution assessment shall represent a compatible substrate for the printer, and must conform to the manufacturer's list of approved substrates. The substrate manufacturer, substrate name, weight, coating, surface characteristics, and size shall be documented in the test report.

5.4 Test platform connection to the printer

Connection to the computer serving as the platform for printer resolution testing should be determined by the manufacturer's targeted usage. Connection type, version, and all settings that differ from the printing device defaults shall be documented in the test report.

5.5 Test charts

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.

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

5.6 Sample size

A single cleanly printed sample of the native addressability test chart is required for visual evaluation. A minimum of ten samples of each of the objective test charts used for measurement according to this Technical Specification shall be printed for each printer set-up configuration. The residual noise of the printing process is substantially reduced in the assessment analysis by averaging measurements over this number of prints, and will be further reduced with use of a larger number of sample prints. The number of sample prints utilized in the analysis of the print quality characteristics contributing to perceived resolution shall be documented in the test report.

5.7 Printing process

The procedure specified in Annex B (normative), Printing process, shall be used to submit the printer resolution assessment test charts for use with this technical specification to the printer being assessed. The name, version, and settings of the low-level printing application used to submit the test charts, as specified in Annex B, shall be recorded in the test report. The printing process specified in this Technical Specification avoids the re-interpretations of test chart content provided by many imaging or graphics applications. This assessment of printer resolution characteristics is made independent of application features and is therefore representative of the inherent capability of the printer.

The printer and printing application settings 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.

5.8 Set-up procedure

1) Qualify the reflection scanner and the scanner control application that will be used for assessment measurement according to Annex C. Re-qualification is not required for each assessment.

2) Qualify the ISO/IEC TS 29112 measurement method implementations used to analyze scanned data from printed test charts according to Annex D.

3) Obtain and install the low-level printing application specified in Annex B.

4) Perform printer maintenance according to the printer manufacturer's User's Manual.

5) Set up and configure the printer according to clauses 5.1 through 5.4 and record the printer configuration.

6) Configure the printing application according to Annex B and record the printing application settings.

7) Use the test charts in the distribution media of this Technical Specification.

5.9 Testing procedure for visual evaluation

1a) Print a copy of the visual evaluation test chart for this technical specification using the configured low-level printing application, the configured printer driver, and the configured printer, according to the printing process specified in Annex B (normative). A single clean print is all that is required for visual evaluation.

2a) Evaluate the printed test chart visually according to the method specified in clause 4.2.1.

3a) If required, edit the copy of the visual evaluation test chart according to the method specified in clause 4.2.1.

4a) Iterate steps 1a), 2a) and 3a) until an unambiguous visual evaluation result is obtained

5a) Record the results of the visual evaluation printer native addressability.

5.10 Testing procedure for scanner-based measurement

1b) Configure the scanner control application according to Annex C and record the application settings.

2b) Print at least ten samples (see clause 5.6) of each of the instrumental measurement test charts for use with this technical specification using the configured low-level printing application, the configured printer driver, and the configured printer, according to the printing process specified in Annex B (normative).

3b) Scan each of the printed samples of the test charts using the qualified scanner with the configured scanner application and save lossless image files of each print sample according to Annex C.

4b) Analyze the image files of each print sample using the qualified analysis methods for this technical specification. Record the name and version of each of the analysis method applications used. Record the analysis results. The multiple samples are properly averaged in the analysis method to create a single, more accurate result.

6 Presentation of results

6.1 General

A report presenting the results of a printer resolution assessment according to ISO/IEC TS 29112 shall include the information specified in this section. Representative samples of test reports can be found in Annex E, (Informative) Test Reports.

The operating configuration in which a printing system is assessed is as important as the measurement results. Each change in the printer settings represents a new printing system configuration and requires a new assessment.

Note 1: Two particularly useful printer resolution assessment configurations are:

- The printer manufacturer's default printer configuration which is representative of the majority use of a printing system, and

- The configuration representing the printer manufacturer's recommended 'best practice' for optimal printing, generally providing a higher perceived resolution.

The information required in an assessment report of printer resolution according to ISO/IEC TS 29112 may be divided into two categories: Assessment configuration documentation, and assessment measurement results. Assessment configuration documentation is specified in clause 6.2 and Table 6. The requirements for reporting assessment measurement results are specified in clause 6.3 and Tables 7, 8 and 9.

6.2 Required test documentation

The information required to document the assessment of printer resolution is specified in Table 6. The required documentation shall include:

- Documentation of the printer, its state at the time of assessment, and the setup configuration of the printer for the assessment.
- Documentation of the substrate used for assessment and the environmental conditions at the time of the assessment.
- Documentation of the print submission process.
- Documentation of the setup and capability of the scanner and scanner control application used for measuring the printer resolution characteristics as well as the method used to compensate for a finite scanner MTF characteristic (see Annex C.5, Method of compensation for finite scanner MTF).

Table 6, Test context documentation for an assessment report

Item:	Information:	Units:
Test date:	dd-Month-yyyy	
Tester or Testing Organization:	xxxxxxxxxxxxxxxxxxxx	
Printer manufacturer and model:	Manufacturer-Name, Model-Number	
Printer configuration:	Printer configuration (with documentation of differences from default settings)	
Total printer print count:	NNNN	
Component print count(s):	Print counts of components (e.g. reported by the printer)	
Printing consumables:	Manufacturer of printing consumables	
Environmental conditions:	e.g. 25°C, 45% RH, 110V, 60Hz	°C, % RH, V, Hz
Identification of substrate used for testing:	Paper-Manufacturer-Name, Paper-Name,	
Characteristics of substrate used for testing:	Paper-weight, Paper-coating, Paper-surface, and Paper-size	
Operating system and version used:	OS name, OS version	
Connection type and version:	Protocol and version used to connect the printer to the test platform	
Printing application:	Application name and version (and documentation of settings different from Annex A) (e.g. PrintFile v2.1.6 for Windows, drag & drop for Mac)	
Number of prints analyzed with each method:	e.g. 10	
Scanner used for measurement:	Manufacturer-Name, Model-Number	
Scanner driver version & configuration:	Driver version #, 'Defaults' (and documentation of settings different from driver defaults)	
Scanner control application:	Application name and version (and documentation of settings different from Annex C)	
Resolution setting used for measurement:	PPPP dpi	dpi
Scanner OECF compensation method & aim:	auto_OECF_WG4.exe, Lightness aim	
Scanner MTF compensation method:	Compensate_scanner_MTF_WG4.exe, v1.0	
Evaluated scanner MTF:	cy/mm @ 50% MTF, cy/mm @ 10% MTF	cy/mm

The intent of this test documentation is to provide a complete context of the setup and testing processes of the resolution assessment. The elements in the test report should be in a logical order. Table 6 shows the test context documentation for an assessment report. Examples of test reports are provided in Annex E, (Informative) Test Reports.

6.3 Reporting of measurement results

Each of the measurement methods specified in ISO/IEC TS 29112 are intended for the engineering evaluation of a printing system's perceived resolution and should not be used for purposes of advertising claims.

Several important characteristics of a printing system's perceived resolution may be assessed using the methods specified in ISO/IEC TS 29112. These characteristics may be measured and reported singly, as a complete group, or in a subset of the available resolution characteristic measurements. The name of the characteristic, its orientation, its measured value, and the units of the measured value shall be reported along with a description of the test chart and analysis method employed for the measurement. The elements in the test report should be in a logical order. Results for multiple orientations of printer resolution characteristics may be reported in any arrangement as long as the presentation of the results is clear. Similarly, the results for assessments of multiple printing system configurations may be reported in any arrangement as long as the presentation of the results is clear and redundancy is avoided. Table 7 shows a template form for reporting the measurement name, orientation, values, and units. Table 8 shows a template form for description of the test chart and analysis method employed for the measurement.

Table 7. Test results documentation for a measurement.

Item:	Orientation	Information:	Units:
Measurement name (e.g. Edge blurriness):	In-track, Cross-track or Angled (value°)	values (mean & stdev)	(e.g. microns)
Measurement name (e.g. Edge raggedness):	In-track, Cross-track or Angled (value°)	values (mean & stdev)	(e.g. microns)

Table 8. Description of test chart and analysis method.

Item:	Information:
Test chart name (e.g. edge_characteristics.eps)	Test chart version
Analysis method name (implementor)	Analysis method implementation version

These template forms should be used for reporting the results of each measurement carried out according to this Technical Specification. For measurements that share the same test chart and analysis method, there is no need to report the test chart name and analysis method in duplicate. The measurements defined by this Technical Specification are summarized in Table 9.

Table 9. Test measurements.

Item:	Orientation	Information:	Units:
Native addressability:	In-track, or Cross-track	values (mean & stdev)	spots/in or spots/mm
Effective addressability:	In-track, or Cross-track	values (mean & stdev)	spots/in or spots/mm
Edge blurriness:	In-track, Cross-track or Angled (value°)	values (mean & stdev)	microns
Edge raggedness:	In-track, Cross-track or Angled (value°)	values (mean & stdev)	microns
Perceived sharpness (CMTA - edge)	In-track, Cross-track or Angled (value°)	values (mean & stdev)	CMTA value
SFR @ 50% MTF (edge):	In-track, Cross-track or Angled (value°)	values (mean & stdev)	cy/mm @ 50% MTF
Limiting resolution (edge):	In-track, Cross-track or Angled (value°)	values (mean & stdev)	cy/mm @ 10% MTF
Perceived sharpness (CMTA - line)	In-track, Cross-track or Angled (value°)	values (mean & stdev)	CMTA value
SFR @ 50% MTF (line)	In-track, Cross-track or Angled (value°)	values (mean & stdev)	cy/mm @ 50% MTF
Limiting resolution (line):	In-track, Cross-track or Angled (value°)	values (mean & stdev)	cy/mm @ 10% MTF

Annex A
(normative)

Test charts

A.1 Availability

The test charts for the evaluation of printer resolution are specified in this Annex, 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.

Native addressability:	ADDIN180_TestChart.eps
Effective addressability:	EffAddr03_IT.eps EffAddr03_XT.eps
Edge characteristics:	EdgeMetric_v8_TestChart.eps
Square-wave MTF:	SqWv_MTF30.eps

Table A1. Test charts.

A.2 Native Addressability test chart content

The native addressability test chart contains three sets of elements:

1) Printing configuration check elements:
These elements are visually evaluated to verify that the printing configurations allow correct assessment of the native addressability test chart. All four checkerboard patterns and all levels of the tone scale ramp should be evident and distinct.

2) Coarse native addressability assessment scales:
A cross-track and an in-track scale 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.

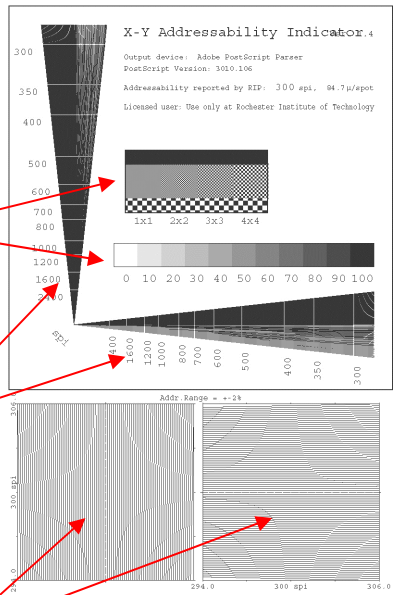


Figure A1
Figure A1 Native addressability.

3) Fine native addressability assessment scales:
A cross-track and an in-track scale are provided to estimate the native addressability of a printing system to much higher precision. Visual assessment of the position where Moire patterns in these elements disappear and the adjacent resolution scales provides an indication of the native addressability of the printing system under assessment.

A.3 Effective Addressability test chart content

The effective addressability test chart contains a cross-track and an in-track effective addressability assessment element. These elements consist of a repeated set of incrementally displaced line segments, each printed adjacent to a reference line. A representation of one of these elements is shown here.

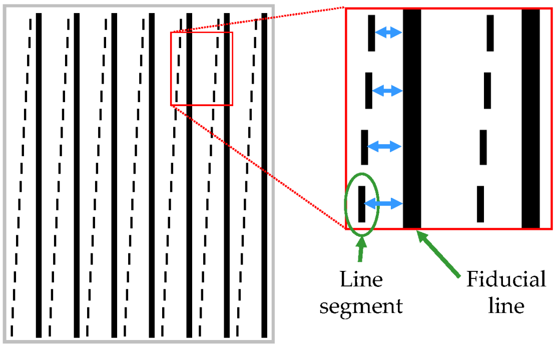
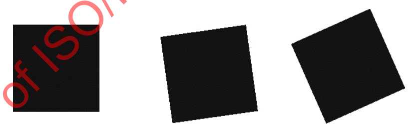


Figure A2. Effective Addressability test chart.

A.4 Edge Characteristics test chart content

Edge blurriness and edge raggedness are estimated using a variant of the line blurriness metric and raggedness metric defined in ISO/IEC TS 24790 method. The three chart objects employed for this analysis are illustrated here. The square element aligned parallel to the page edges is utilized to estimate the edge blurriness and raggedness of edges aligned parallel and perpendicular to the page edges. The square elements printed at angled orientations are utilized to estimate the blurriness and raggedness of angled edges.



Edges are provided at 0°, 90°, 8°, 82°, 24° and 66° orientations.

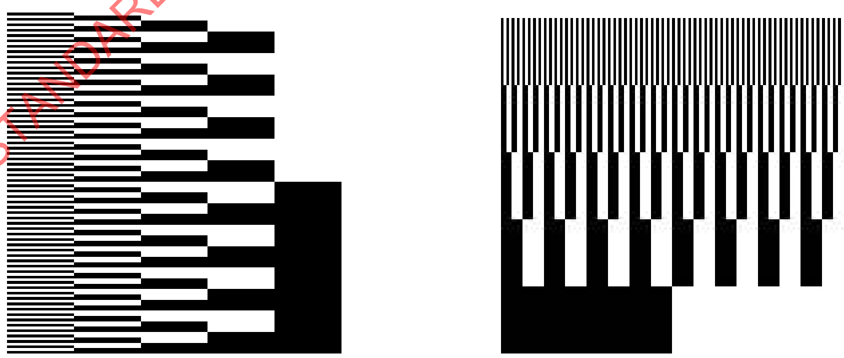
Figure A3. Edge metric test chart.

The printer Modulation Transfer Function can be estimated by analysis of the edge profile characteristics of these target elements.

A.5 Line Characteristics test chart content

A second estimate of the printer Modulation Transfer Function is provided by analysis of two square-wave test chart objects that create cross-track and in-track binary patterns of dark and light lines aligned with the printing grid of the printer under assessment. The square-wave objects are sensitive to edge characteristics, spot-size, and one-dimensional adjacency effects.

With these multiple estimates of the printer Modulation Transfer Function, the contributors to detail carrying capability from edge characteristics, from spot-size effects, from spot-shape effects and from one-dimensional adjacency effects can be estimated.



0° orientation 90° orientation

Figure A4. Square-wave MTF test chart.

Annex B
(normative)

Printing process

B.1 Application effects

Imaging and graphics applications generally have their own individual ideas about how a graphics file should be printed. These ideas have been known to change from version to version. Printing ISO/IEC TS 29112 test chart files from an imaging or graphics application is not recommended due to the many changes that an application can make to the intent of the standardized printing files utilized in the ISO/IEC TS 29112 assessment of printer resolution.

B.2 Print driver effects

Printer drivers often attempt to assist the user in printing information. This assistance can destroy the attempt to analytically estimate printer resolution and must be avoided. Printer drivers are an essential part of the printing data path, but can be accessed at a low level to avoid unnecessary assistance.

B.3 Test chart files for Postscript printers

The test chart files for ISO/IEC TS 29112 assessment of Postscript printer resolution are in EPS (Encapsulated PostScript) format. This is a well-documented, freely usable Adobe format that can be sent directly to Postscript compatible printers from a Windows, Linux, or Macintosh platform. The ISO/IEC TS 29112 printer resolution test chart files are able to adapt to the characteristics of the printer under assessment. This adaptation takes two forms: 1) dynamic adaptation, and 2) static adaptation.

With dynamic adaptation, an EPS file sent to the printer under assessment queries the printer RIP for information. The information requested is the cross-track and in-track native addressability of the printer and printer identification information such as name, version, time, and date that are subsequently displayed as informative text in the printed test chart. The cross-track and in-track native addressability data returned by the printer is also utilized to precisely configure the test chart to the printer characteristics. This adaptation avoids a mismatch between the resolution assessment test chart file addressability and the printer addressability, as long as the printer correctly reports its own addressability. Dynamic adaptation is the default state of the ISO/IEC TS 29112 printer resolution test chart files.

With static adaptation, the user can over-ride a dynamic configuration of the test chart. With static adaptation, the user edits the header portion of the test chart file to explicitly define the cross-track and in-track addressability to be utilized in configuring the test chart for the actual addressability of a printer. These edited values are used instead of the addressability reported by the printer in configuring the test chart file for printing.

Note: The PDF format is not employed due to the static (compiled) nature of this format which does not allow a single PDF file to adapt to different printer addressabilities.

B.4 Printing protocol

For a Microsoft Windows® platform, a low-level printing utility such as PrintFile (www.lerup.com/printfile) is recommended as the mechanism for sending ISO/IEC TS 29112 resolution assessment test chart files to a printer. This utility connects to the Windows printer driver of the printer under assessment at a low level and directly transfers the test chart information to the printer, thus avoiding the application and driver effects mentioned above. Some configuration of the PrintFile utility is required, as specified here. With the PrintFile application running, click on the Settings button, then in the More pane, click on the Postscript button.

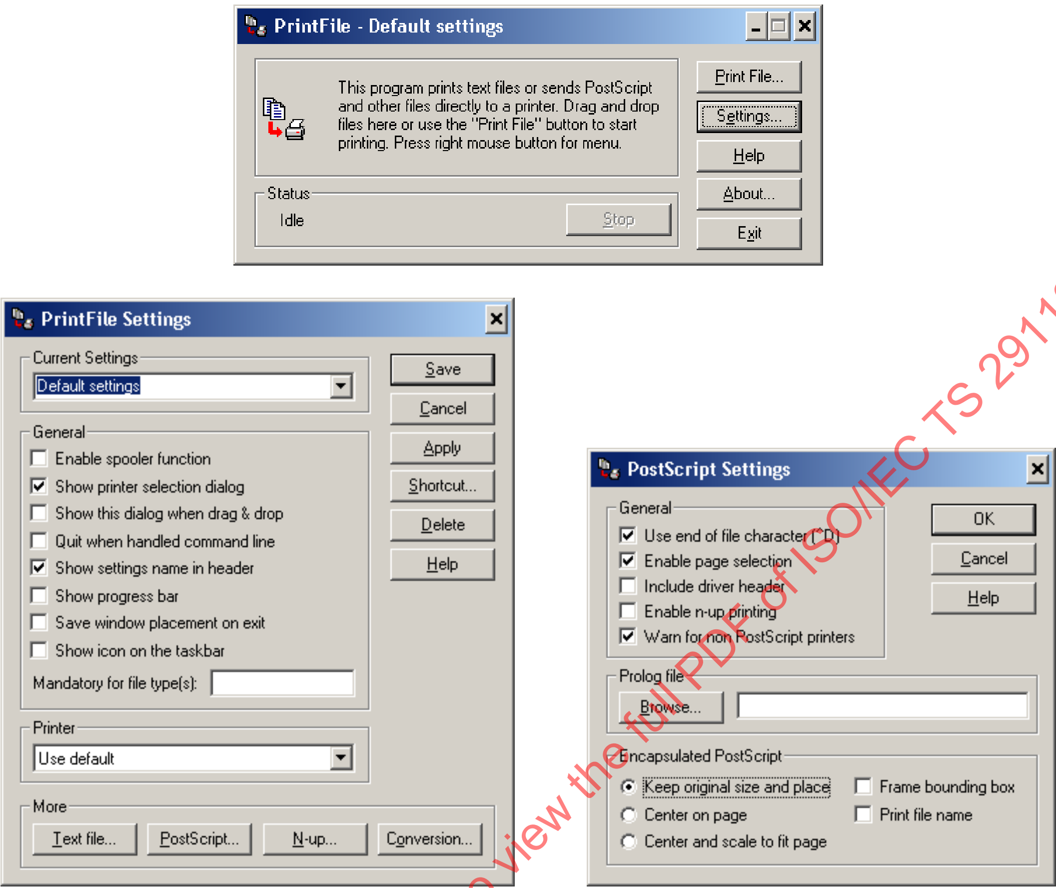


Figure B1, PrintFile configuration

In the Encapsulated PostScript pane of this dialog box, check the "Keep original size and place" button and then click the “OK” button of the PostScript Settings dialog box and the “Apply” button of the PrintFile Settings dialog box. If any of the test chart content is clipped by printing boundaries, the "Center on page" button may be utilized. Do not use the "Center and scale to fit page" button" as this shall invalidate the measurements. This completes the configuration of the PrintFile utility.

On a Macintosh platform, the test chart file should be directly dragged to the icon of the printer under assessment. This process explicitly avoids the application and upper-level driver effects mentioned above.

Annex C
(normative)

Scanner conformance

Many of the measurement methods utilized in this Technical Specification to estimate the characteristics of printer resolution 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 pristine imagery. This annex specifies the conditions that shall be met by a reflection scanner and its scanner control application to qualify a scanner as a usable measurement device for use with this Technical Specification.

C.1 Required scanner characteristics

Four characteristics of a reflection scanner shall be evaluated in order to qualify a reflection scanner for use with this Technical Specification. hese characteristics are:

- The tone-scale or opto-electronic conversion function (OECF) characteristics of the scanner,
- The dynamic range capability of the scanner (minimum to maximum reflectance, free of saturation effects),
- Interpolation effects in the sensor array of the scanner, and
- The usable addressability or spatial frequency response characteristics of the scanner.

Several other characteristics of a reflection scanner can affect the measurements utilized in this Technical Specification, but are generally sufficiently well controlled in commercially available reflection scanners to be of small concern. These characteristics are:

- The geometric distortion of the scanner,
- The flare or integrating cavity effects of the scanner, and
- The scan uniformity over the tone scale and stability over time.

C.1.1 Scan characteristics

A reflection scanner employed for measurement with this Technical Specification shall be capable of capturing a wide range of tonal levels between the maximum reflectance of the test chart elements and the minimum reflectance of the test chart elements utilized in this Technical Specification. Scans of test charts shall not exhibit any clipping or saturation effects. The reflection scanner shall be capable of providing at least 256 different tonal levels. This corresponds to at least an 8-bit scanner data path.

The dynamic range of a scanner utilized for measurement according to this Technical Specification shall permit accurate measurement of print reflectance values over the range produced by the printing system being tested.

The filter array of the sensor used in the scanner must not compromise the spatial resolution of scanned data. Scanners utilizing multiple sensors, one for each colour can qualify for use with this Technical Specification. Scanners utilizing a single linear sensor with an alternating colour filter array will compromise the spatial resolution of scanned data and may not be used since spatial information is interpolated.

The scanner spatial uniformity and temporal stability shall permit calibration of the scanner to provide a monotonic OECF characteristic that does not saturate at either end of its range for the reflection characteristics of the printed test charts utilized in this Technical Specification.

C.1.2 Scanner MTF characteristics

The detail carrying capability of scans provided by the reflection scanner used for measurement in this Technical Specification shall significantly exceed the detail carrying capability of the printer system that is being evaluated with the protocol specified in this Technical Specification. The usable addressability of the scanner shall be at least twice the specified addressability of the printing system being evaluated. The conformance requirement for the measured scanner MTF characteristic is specified in clause C.4.

C.2 Method for evaluating the scanner OECF characteristic

A fully populated look-up-table (LUT) that captures the calibrated OECF characteristic of the scanner is required by the assessment methods employed by this Technical Specification. Calibration of a reflection scanner in the form of this required LUT shall be done in accordance with the procedure defined in ISO 14524. The standard error of the scanner calibration shall be less than 1% of the range utilized by the printed test charts.

C.3 Method for evaluating scanner dynamic range

The scanner utilized for measurement according to this Technical Specification shall provide a dynamic range that permits accurate measurement of print reflectance values over the range produced by the printing system being tested. The dynamic range measurement requires a test chart exhibiting both very good uniformity and a very wide range of reflectance values (e.g. the Munsell Neutral Value Scale available through X-Rite Corporation[2]). Evaluation of scanner dynamic range shall be done in accordance with the procedure defined in ISO 21550 from multiple scans of a uniform, wide reflectance range target, such as the Munsell Neutral Value Scale. The scanner dynamic range shall be at least as large as the reflection density range of the printing system to be evaluated.

C.4 Method for evaluating scanner usable addressability

The detail carrying capability of a scanner shall be evaluated in accordance with the procedure defined in ISO 16067-1 Photography: Spatial resolution measurements of electronic scanners for photographic images. The modulation transfer function (MTF) of the scanner, at the spatial frequency corresponding to the addressability of the printer being assessed, shall be greater than 25%, preferably at least 50%. The usable addressability of a scanner is proportional to the spatial frequency at 50% MTF of the scanner. This spatial frequency is converted to usable addressability by multiplying by 50.8 (2 pixels are required for a minimum printer cycle). The scanner usable addressability at 50% MTF should be comparable to the printer addressability.

Scanner usable addressability @ 50% MTF = (Measured scanner spatial frequency @ 50% MTF) * 50.8

C.5 Method for compensating for finite scanner MTF

The MTF characteristics of the scanner employed for test chart measurement in the protocol of this Technical Specification shall be taken into account in the assessment of printer MTF characteristics. The estimated printer MTF, and hence the resolution characteristics of this printer, will be underestimated without compensation for the measured scanner MTF. Compensation for scanner MTF in printer MTF assessment shall avoid over-amplification by limitation of the compensated scanner MTF characteristic to a value of 0.33. This results in a maximum amplification of noise in the compensated MTF characteristic by a factor of 3. This compensation method is incorporated in the reference implementations of the measurement methods specified in this Technical Specification.

C.6 Required scanner control application characteristics

Like imaging and graphics applications, scanner control applications are designed to help the user to produce aesthetically pleasing imagery. This aim is usually at odds with the requirement of providing analytic measurements that are accurate and repeatable. A scanner control application that is usable for analytic measurement in the ISO/IEC TS 29112 assessment of printer resolution shall be capable of being run in a completely manual manner. All automatic features of the application that are designed to enhance the scanned image shall be disabled. In particular:

- Any auto-exposure capability shall be disabled.
- Any automatic tone-scale correction capability shall be disabled.
- Any filtering of the scanned imagery (e.g. sharpening, un-sharp masking, blurring, etc) shall be disabled.
- Any colour management capability shall be disabled.
- Scanned imagery shall be capable of being saved in a lossless format (e.g. LZW or ZIP).

Annex D
(normative)

Measurement method conformance

Measurement methods employed for use with this Technical Specification shall conform to the reference implementations specified in this Annex. The code listings of these reference implementations define the data analysis process for each of the measurement methods used in this Technical Specification from bitmap file to measurement result. A set of reference bitmap files are provided for each of the defined measurement methods, along with their expected reference implementation measurement results, for compliance testing of alternative implementations of the defined measurement methods. An alternative implementation of a measurement method is compliant with the reference implementation of that measurement method defined in this Technical Specification if the measurement results from the alternate implementation agree with the provided expected results from the reference implementation within effective computational rounding error for all files of the corresponding set of reference bitmap files. The reference implementation listings and the reference bitmap file sets for compliance testing are included in the distribution media of this Technical Specification. The ZIP file TS29112_Conformance contains the reference bitmap files. The ZIP file TS29112_Reference contains the reference implementations for each of the measurement methods specified in this Technical Specification. The expected values for conformance testing using the reference bitmap files are specified in the tables of this Annex.

Failure to use a compliant implementation of the measurement methods defined in this Technical Specification shall invalidate any test results obtained using that implementation.

D.1 Effective addressability measurement method

The reference implementation for the effective addressability measurement is specified by the Matlab function EffAddr_v3.m. The input for this reference implementation is the uncompressed TIFF bitmap file EffAddr_RefBitmap.tif. The output result from this reference implementation is the measured effective addressability value.

Figure D1 shows the graphical output of an evaluation of the reference bitmap image with the effective addressability reference implementation specified in Table D1. A conforming implementation of the effective addressability method shall provide a result that closely resembles Figure D1 with two well separated peaks.

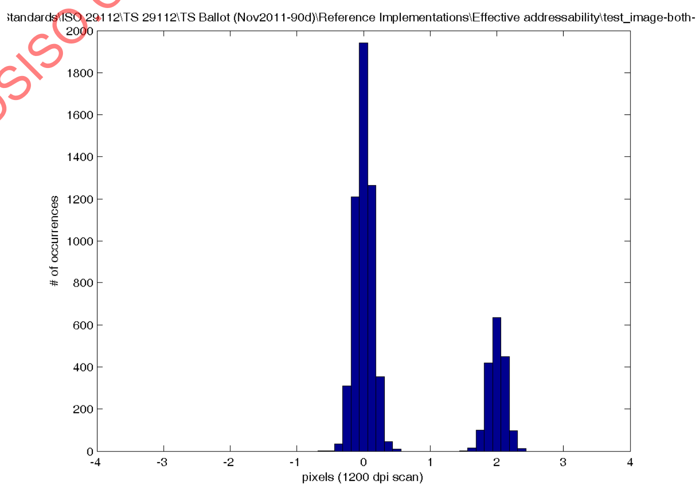


Figure D1. Expected results for effective addressability