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Third edition

Information technology, Automatic identification and data capture techniques — Bar code symbol print quality test specification — Two-dimensional symbols

Technologies de l'information — Techniques automatiques d'identification et de capture des données — Spécification de test de qualité d'impression des symboles de code à barres — Symboles bidimensionnels

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

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

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This third edition cancels and replaces the second edition (ISO/IEC 15415:2011) which has been technically revised.

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The main changes are as follows:

— a continuous (or decimal) grading has been introduced;

— a more optimal threshold calculation has been introduced;

— a more stable symbol contrast calculation has been introduced;

— a definition of grading for print growth has been added;

— combination of modulation and reflectance margin into a single measurement.

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

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Introduction

The technology of bar coding is based on the recognition of patterns encoded, in bars and spaces or in a matrix of modules of defined dimensions, according to rules defining the translation of characters into such patterns, known as the symbology specification. Symbology specifications may be categorised into those for linear symbols, on the one hand, and two-dimensional symbols on the other; the latter may in turn be subdivided into “multi-row bar code symbols” sometimes referred to as “stacked bar code symbols”, and “two-dimensional matrix symbols”. In addition, there is a hybrid group of symbologies known as “composite symbologies”; these symbols consist of two components carrying a single message or related data, one of which is usually a linear symbol and the other a two-dimensional symbol positioned in a defined relationship with the linear symbol.

Multi-row bar code symbols are constructed graphically as a series of rows of symbol characters, representing data and overhead components, placed in a defined vertical arrangement to form a (normally) rectangular symbol, which contains a single data message. Each symbol character has the characteristics of a linear bar code symbol character and each row has those of a linear bar code symbol; each row, therefore, may be read by linear symbol scanning techniques, but the data from all the rows in the symbol must be read before the message can be transferred to the application software.

Two-dimensional matrix symbols are normally square or rectangular arrangements of dark and light modules, the centres of which are placed at the intersections of a grid of two (sometimes more) axes; the coordinates of each module need to be known in order to determine its significance, and the symbol must therefore be analysed two-dimensionally before it can be decoded. Some matrix codes are comprised of unconnected dots, in which the individual modules do not directly touch their neighbours but are separated from them by a clear space.

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Unless explicitly specified otherwise, the term “symbol” in this document refers to either type of symbology.

The bar code symbol must be produced in such a way as to be reliably decoded at the point of use, if it is to fulfil its basic objective as a machine-readable data carrier.

Manufacturers of bar code equipment and the producers and users of bar code symbols therefore require publicly available standard test specifications for the objective assessment of the quality of bar code symbols, a process known as verification, to which they can refer when developing equipment and application specifications or determining the quality of the symbols. Such test specifications form the basis for the development of measuring equipment for process control and quality assurance purposes during symbol production as well as afterwards.

The performance of measuring equipment for the verification of symbols, also known as verifiers, is covered in ISO/IEC 15426-1 and ISO/IEC 15426-2.

The methodology described in this document is intended to achieve comparable results to the linear bar code symbol quality standard ISO/IEC 15416, the general principles of which this document has followed. It should be read in conjunction with the symbology specification applicable to the bar code symbol being tested, which provides symbology-specific details necessary for its application. Two-dimensional multi-row bar code symbols are verified according to the ISO/IEC 15416 methodology, with the modifications described in Clause 6; different parameters and methodologies are applicable to two-dimensional matrix symbols. The procedures described in this document must necessarily be augmented by the reference decode algorithm and other measurement details within the applicable symbology specification, and they may also be altered or overridden as appropriate by governing symbology or application specifications.

The method of quality assessment described in this document is most applicable to reading environments wherein printed and otherwise marked symbols are read predominantly by diffuse reflection. For direct part mark applications, in which symbols and substrates may be glossy, specular, low contrast, etc., a modified and extended version of the methodology defined in this document has been defined in ISO/IEC 29158 and

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provides for lighting arrangements and enhanced algorithms which more closely match reading equipment commonly used in DPM applications.

NOTE The Bibliography provides official and industry standards containing symbology specifications, among other references, to which this document applies. However, the Bibliography does not provide an exhaustive list of symbology specifications.

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Information technology, Automatic identification and data capture techniques — Bar code symbol print quality test specification — Two-dimensional symbols

1 Scope

This document

- specifies two methodologies for the measurement of specific attributes of two-dimensional bar code symbols – one of which applies to multi-row bar code symbologies and the other to two-dimensional matrix symbologies;
- specifies methods for evaluating and grading these measurements and deriving an overall assessment of symbol quality;
- gives information on possible causes of deviation from optimum grades to assist users in taking appropriate corrective action.

This document applies to two-dimensional symbologies for which a reference decode algorithm has been defined, however the methodologies in this document can be applied partially or wholly to other similar symbologies.

NOTE While this document can be applied to direct part marks, better correlation between measurement results and scanning performance can be obtained with ISO/IEC 29158 in combination with this document.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 19762, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

ISO/IEC 15416, *Information technology – Automatic identification and data capture techniques — Bar code print quality test specification — Linear symbols*

ISO/IEC 15426-2, *Information technology — Automatic identification and data capture techniques — Bar code verifier conformance specification — Part 2: Two-dimensional symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762, ISO/IEC 15416 and the following apply.

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

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3.1
binarised image
binary (black/white) image created by applying a threshold to the *pixel* (3.7) values in the *reference grey-scale image* (3.9)

3.2
effective resolution
resolution obtained on the surface of the symbol under test and calculated as the resolution of the image capture element multiplied by the magnification of the optical elements of the measuring device

Note 1 to entry: The effective resolution is normally expressed in *pixels* (3.7) per mm (or pixels per inch).

3.3
error correction capacity
number of codewords, or units of data, in a symbol (or error control block) assigned for erasure and error correction, minus the amount reserved for error detection

3.4
inspection area
portion of an image which contains the entire symbol to be tested inclusive of its quiet zones

3.5
grade threshold
boundary value separating two grade levels, the value itself being taken as the lower limit of the upper grade

3.6
module error
module of which the apparent dark or light state in the *binarised image* (3.1) is inverted from its intended state

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3.7
pixel
individual light-sensitive element in an array

EXAMPLE CCD (charge coupled device), CMOS (complementary metal oxide semiconductor) device.

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3.8
raw image
plot of the reflectance values in x and y coordinates across a two-dimensional image, representing the discrete reflectance values from each *pixel* (3.7) of the light-sensitive array

3.9
reference grey-scale image
plot of the reflectance values in x and y coordinates across a two-dimensional image, derived from the discrete reflectance values of each *pixel* (3.7) of the light-sensitive array by convolving the *raw image* (3.8) with a *synthesised aperture* (3.10)

3.10
synthesised aperture
convolutional kernel used to blur an image

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4 Symbols and abbreviated terms

4.1 Symbols

E_{cap} error correction capacity of the symbol

D distance across or width of an element in a symbol

D_{NOM} expected or nominal width of an element in a symbol

e number of erasures

M_{MOD} measure of the difference in reflectance between a module and the threshold

M_{ANU} measure of axial nonuniformity

M_{GNU} measure of grid nonuniformity

M_{UEC} measure of unused error correction, accounting for the number of errors, erasures and capacity

R reflectance

R_{max} indicative reflectance of the brightest area of a symbol

R_{min} indicative reflectance of the darkest area of a symbol

ΔR_{SC} symbol contrast, i.e. the difference in reflectance between R_{max} and R_{min}

t number of errors

T threshold

X_{AVG} average spacing of modules in the horizontal axis

Y_{AVG} average spacing of modules in the vertical axis

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4.2 Abbreviated terms

ANU axial nonuniformity

CU contrast uniformity

FPD fixed pattern damage

GNU grid nonuniformity

MOD modulation

PG print growth

SC symbol contrast

UEC unused error correction

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5 Quality grading

5.1 General

The measurement of two-dimensional bar code symbols is designed to yield a quality grade, reported as the symbol grade, indicating the overall quality of the symbol. This can be used by producers and users of the symbol for diagnostic and process control purposes and is broadly predictive of the read performance to be expected of the symbol. The process requires the measurement and grading of defined parameters, from which the symbol grade is derived. The symbol grade is sometimes called the “overall symbol grade” when used in a context in which the modifier “overall” helps to clarify and distinguish the symbol grade from other parameter grades.

As a consequence of the use of different types of reading equipment under differing conditions in actual applications, the levels of quality required of two-dimensional bar code symbols to ensure an acceptable level of performance will differ between different real-world applications. Application specifications should therefore define the required symbol quality in terms of aperture, light (angle, orientation, and wavelength), and minimum symbol grade in accordance with this document. The guidelines in Annex C are provided as an aid in writing application specifications according to this document. Annex D provides additional information regarding substrate properties. When this document is used without an applicable application specification, suitable choices for aperture, light (angle and wavelength), and minimum grade, must be made by the user. However, if these choices are not suited to the intended application, then the achieved symbol grade cannot be relied upon as an indicator of reading performance in the intended application. Thus, it is highly preferred to follow an agreed upon application specification when using this document (such as a specification mutually agreed upon or published by an industry standards body or regulatory authority).

This document defines the method of obtaining a quality grade for individual symbols. The use of this method in high volume quality control regimes may require sampling in order to achieve desired results. Such sampling plans, including required sampling rates are outside of the scope of this document.

NOTE Information on sampling plans can be found in ISO 3951-1, ISO 3951-2, ISO 3951-3, ISO 3951-5 and ISO 28590.

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5.2 Expression of quality grades

This document specifies a numeric basis for expressing quality grades on a descending scale from 4,0 to 0 in steps of 0,1. The highest quality is represented by 4,0. Alphabetic grades are not formal and should not be reported as the formal grade. The link between numeric and alphabetic grades is given in Table 1. Numeric grades are more precise because they express a grade with ten steps within each letter grade range. Overall numeric grades should not be rounded to the nearest whole number. When using alphabetic grades for convenience they shall be accompanied by a numerical grade.

Table 1 shows the correspondence between alphabetic and numeric grades.

Table 1 — Correspondence between numeric and historical alphabetic quality grades

Numeric range	Alphabetic grade
≥3,5 (i.e. 3,5; 3,6; 3,7; 3,8; 3,9; 4,0)	A
2,5 to 3,4	B
1,5 to 2,4	C
0,5 to 1,4	D
≤0,4 (i.e. 0,0; 0,1; 0,2; 0,3; 0,4)	F

5.3 Symbol grade

The symbol grade shall be calculated in accordance with 6.2.6 or 6.3 or 7.6 or Clause 8 and as applicable to the type of symbol.

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5.4 Specifying the symbol grade requirement in an application specification

An application specification shall specify the minimum grade requirement as well as the grading conditions, shown in the format:

grade/aperture/light/angle

where

grade	indicates the minimum grade required;
aperture	indicates the aperture reference number (from ISO/IEC 15416 for linear scanning techniques), or the diameter in thousandths of an inch (to the nearest thousandth) of the aperture defined in 5.6.2;
light	indicates the numeric value of the peak light wavelength (i.e. the illumination) in nanometres (for narrow band illumination); the alphabetic character W indicates broadband (nominally, “white light”), the spectral response characteristics of which must imperatively be defined or specified in kelvin in parenthesis after the W designated by a number followed by the letter K, or have their source specification clearly referenced;
angle	indicates the angle of incidence (an additional parameter) in degrees (relative to the plane of the symbol) of the illumination from four sides (as a default, unless another orientation is specified by an application) – see Figure 1 and Figure 2.

The angle shall be included in the specification of grading requirements when the angle of incidence is other than 45°. While it may be included for 45°, its absence indicates that the specified angle of incidence is 45° by default. Application specifications may specify a different angle of incidence instead of leaving it blank.

The orientation of light refers to the number of directions, the default being four. Light from only two sides may be specified by appending the letter "T" to the angle, such as 30T. The letter "S" may be used to indicate only one side. The letter "Q "may be used to indicate four sides, but omitting it implies four sides so 45Q is equivalent to 45 but 45Q is explicit regarding the orientation.

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EXAMPLE 1 An application specification can specify a symbol quality requirement as 1,5/05/660 to indicate that the required symbol quality is 1,5 or higher obtained using an aperture size of 0,125 mm (reference number 05) with 660 nm light incident from 45° from four sides.

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EXAMPLE 2 Using a white light with 5400 K, the light source is 1,5/05/W(5400 K).

Other lighting options are defined in ISO/IEC 29158 which can be more appropriate for direct part marking applications, especially in applications which utilize symbols marked on reflective substrates. Therefore, ISO/IEC 29158 should be specified by an application specification as the method of grading when such lighting options are preferred in an application.

5.5 Reporting of symbol grade

A symbol grade is only meaningful if it is reported in conjunction with the illumination and aperture used. It should be shown in the format:

grade/aperture/light/angle

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where

grade indicates the symbol grade as defined in 5.3;

aperture indicates the aperture reference number (from ISO/IEC 15416 for linear scanning techniques, or the diameter in thousandths of an inch (expressed to the nearest thousandth or a to higher precision) of the aperture defined in 5.6.2;

light indicates the numeric value indicates the peak light wavelength (i.e. the illumination) in nanometres (for narrow band illumination); the alphabetic character W indicates that the symbol has been measured with broadband illumination ("white light") the spectral response characteristics of which must imperatively be defined or have their source specification clearly referenced;

angle indicates the angle of incidence (an additional parameter, relative to the plane of the symbol) of the illumination from four sides.

The angle shall be included in the reporting of the overall symbol grade when the angle of incidence differs from the default orientation of 45° from four sides. While it may be included for the default orientation, its absence indicates that the angle of incidence is 45° from four sides.

The notation used to specify a minimum grade that is required in an application is similar to the notation used to report a grade result, but the grading requirement specifies a minimum for the grade in an application, whereas the result specifies a specific occurrence of a grade produced by verifying a symbol.

EXAMPLE 1 2,8/05/660 indicates that the overall grade was 2,8 and was obtained with the use of a 0,125 mm aperture (reference number 05) and a 660 nm light source, incident at 45° from four sides.

EXAMPLE 2 2,8/10/W/30Q indicates that the grade of a symbol was 2,8 and was obtained with broadband light, measured with light incident at 30° from four sides and using a 0,250 mm aperture (reference number 10), but would need to be accompanied either by a reference to the application specification defining the reference spectral characteristics used for measurement or a definition of the spectral characteristics themselves.

EXAMPLE 3 2,8/10/670 indicates that the grade of a symbol was 2,8 and was obtained using a 0,250 mm aperture (reference number 10), and a 670 nm light source, incident at 45° from four sides.

NOTE The previous edition of this document defined the use of a * to indicate the presence of extreme reflectance in or near the symbol. This has been removed in this edition of this document.

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5.6 Optical setup and obtaining the test images

5.6.1 General requirements

Equipment for assessing the quality of symbols in accordance with this clause shall comprise a means of measuring and analysing the variations in the reflectivity of a symbol on its substrate over an inspection area which shall cover the full height and width of the symbol including all quiet zones. All measurements on a two-dimensional matrix symbol shall be made within the inspection area defined in accordance with 5.6.4.

The measured reflectance values shall be expressed in percentage terms by means of calibration to a reference reflectance standard traceable to National Measurement Institutes.

NOTE Maximum white diffuse reflectance is taken as 100 %.

The peak light wavelength or, in the case of applications designed for the use of broadband illumination, the reference spectral response characteristics, should be specified in the application specification to suit the intended scanning environment. Light sources may either have inherently narrow band or near-monochromatic characteristics or have broad bandwidths. Special care is necessary when making measurements with broadband illumination. The overall spectral response of the measurement and reading systems shall be defined and matched in order to make accurate and repeatable measurements of the grey-scale reflectance of a sample area that correlate with the intended system. Overall spectral response includes the spectral distribution of the light source, the response of the detector and any associated filter characteristics.

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