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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. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 15415 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 15415:2004), which has been technically revised. It also incorporates the Technical Corrigendum ISO/IEC 15415:2004/Cor.1:2008.

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 sub-divided 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. Dot codes are a subset of matrix codes in which the individual modules do not directly touch their neighbours but are separated from them by a clear space.

Unless the context requires otherwise, the term "symbol" in this International Standard may refer 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 standards 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 (verifiers) is the subject of a separate International Standard (ISO/IEC 15426, Parts 1 and 2).

This International Standard is intended to achieve comparable results to the linear bar code symbol quality standard ISO/IEC 15416, the general principles of which it has followed. It should be read in conjunction with the symbology specification applicable to the bar code symbol being tested, which provides symbology-specific detail 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.

There are currently many methods of assessing bar code quality at different stages of symbol production. The methodologies described in this International Standard are not intended as a replacement for any current process control methods. They provide symbol producers and their trading partners with universally standardized means for communicating about the quality of multi-row bar code and two-dimensional matrix symbols after they have been printed. The procedures described in this International Standard 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.

Alternative methods of quality assessment may be agreed between parties or as part of an application specification.

For direct part mark applications, a modified version of the methodology defined in this International Standard has been defined in ISO/IEC TR 29158.

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

1 Scope

This International Standard

— specifies two methodologies for the measurement of specific attributes of two-dimensional bar code symbols, one of these being applicable to multi-row bar code symbologies and the other to two-dimensional matrix symbologies;

— defines 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 International Standard applies to those two-dimensional symbologies for which a reference decode algorithm has been defined, but its methodologies can be applied partially or wholly to other similar symbologies.

While this International Standard can be applied to direct part marks, it is possible that better correlation between measurement results and scanning performance will be obtained with ISO/IEC TR 29158 in combination with this International Standard.

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/IEC 19762-1, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 1: General terms relating to AIDC*

ISO/IEC 19762-2, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 2: Optically readable media (ORM)*

ISO 7724-2:1984, *Paints and varnishes — Colorimetry — Part 2: Colour measurement*

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

NOTE The Bibliography lists official and industry standards containing specifications of symbologies to which (inter alia) this International Standard is applicable.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762-1, ISO/IEC 19762-2, ISO/IEC 15416 and the following apply.

3.1
binarised image
binary (black/white) image created by applying the Global Threshold to the pixel values in the reference grey-scale image

3.2
effective resolution
resolution obtained on the surface of the symbol under test, normally expressed in pixels per millimetre or pixels per inch, and calculated as the resolution of the image capture element multiplied by the magnification of the optical elements of the measuring device

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

3.4
inspection area
rectangular area 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 is inverted from its intended state

3.7
pixel
individual light-sensitive element in an array [e.g. CCD (charge coupled device) or CMOS (complementary metal oxide semiconductor) device]

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 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 of the light-sensitive array by convolving the raw image with a synthesised circular aperture

3.10
reflectance margin
measurement of modulation using error correction and known module colours

3.11
sample area
area of an image contained within a circle 0,8X in diameter, X being the average module width determined by the application of the reference decode algorithm for the symbology in question or, where the application permits a range of X dimensions, the minimum module width permitted by the application specification

3.12
scan grade
result of the assessment of a single scan of a matrix symbol, derived by taking the lowest grade achieved for any measured parameter of the reference grey-scale and binarised images

4 Symbols and abbreviated terms

AN = Axial Nonuniformity

E_{cap} = error correction capacity of the symbol

e = number of erasures

FPD = Fixed Pattern Damage

GN = Grid Nonuniformity

GT = Global Threshold

MARGIN = a measure of the difference in reflectance between a module and the global threshold, the value of which goes to zero for modules of the incorrect reflectance state

MOD = an absolute measure of the difference in reflectance between a module and the global threshold

R_{max} = highest reflectance in any element or quiet zone in a scan reflectance profile, or the highest reflectance of any sample area in a two-dimensional matrix symbol

R_{min} = lowest reflectance in any element in a scan reflectance profile, or the lowest reflectance of any sample area in a two-dimensional matrix symbol

SC = Symbol Contrast (equal to R_{max} - R_{min})

t = number of errors

UEC = Unused Error Correction

5 Quality grading

5.1 General

The measurement of two-dimensional bar code symbols is designed to yield a quality grade indicating the overall quality of the symbol which can be used by producers and users of the symbol for diagnostic and process control purposes, and which is broadly predictive of the read performance to be expected of the symbol in various environments. The process requires the measurement and grading of defined parameters, from which a grade for an individual scan (scan reflectance profile grade or scan grade) is derived; the grades of multiple scans of the symbol are averaged to provide the overall symbol grade.

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. Application specifications should therefore define the required performance in terms of overall symbol grade in accordance with this standard. The guidelines in Annex D.4 are provided as an aid in writing application standards which employ this standard.

This standard 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 international standard.

NOTE Information on sampling plans may be found in the following: ISO 3951-1, ISO 3951-2, ISO 3951-3, ISO 3951-5 or ISO 2859-10.

5.2 Expression of quality grades

Although this International Standard specifies a numeric basis for expressing quality grades on a descending scale from 4 to 0, with 4 representing the highest quality, individual parameter grades and individual scan grades may also be expressed on an equivalent alphabetic scale from A to D, with a failing grade of F, in application standards with a historical link to ANSI X3.182.

Table 1 maps the alphabetic and numeric grades to each other.

Table 1 — Equivalence of numeric and alphabetic quality grades

Numeric grade	Alphabetic Grade
4	A
3	B
2	C
1	D
0	F

5.3 Overall Symbol Grade

The overall symbol grade shall be calculated as defined in 6.2.6 or 7.10. Overall symbol grades shall be expressed to one decimal place on a numeric scale ranging in descending order of quality from 4,0 to 0,0.

Where a specification defines overall symbol grades in alphabetic terms the relative mapping of the alphabetic and numeric grades is as illustrated in Figure 1 below. For example, the range of 1,5 to immediately below 2,5 corresponds to grade C.

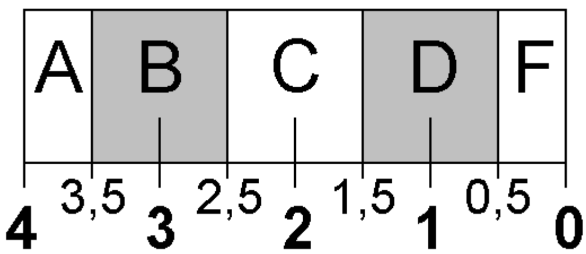

Figure 1 — Mapping of alphabetic and numeric overall symbol grades

5.4 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*, where:

- "*grade"* is the overall symbol grade as defined in 6.2.6 or 7.10, i.e. the arithmetic mean to one decimal place of the scan reflectance profile or scan grades,
- *"aperture"* is 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 synthetic aperture defined in 7.3.3),
- "*light"* defines the illumination: a numeric value indicates the peak light wavelength 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"* is an additional parameter defining the angle of incidence (relative to the plane of the symbol) of the illumination. It shall be included in the reporting of the overall symbol grade when the angle of incidence is other than 45°. Its absence indicates that the angle of incidence is 45°.

NOTE While illumination from four sides with an angle of incidence of 45° is the default, other angles of incidence may be specified as requirements for grading by specifying the angle instead of leaving it blank. Other lighting options are defined in ISO/IEC TR 29158 which may be more appropriate for direct part marking applications, especially in applications which rely on symbols marked on reflectance substrates.

An asterisk following the value for "grade", in the case of a two-dimensional matrix symbol, indicates that the surroundings of the symbol contain extremes of reflectance that may interfere with reading - see 7.6.

Examples

2,8/05/660 would indicate that the average of the grades of the scan reflectance profiles, or of the scan grades, was 2,8 when these were obtained with the use of a 0,125 mm aperture (ref. no. 05) and a 660 nm light source, incident at 45°.

2,8/10/W/30 would indicate the grade of a symbol intended to be read in broadband light, measured with light incident at 30° and using a 0,250 mm aperture (ref. no. 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.

2,8*/10/670 would indicate the grade of a symbol measured using a 0,250 mm aperture (ref. no. 10), and a 670 nm light source, and indicates the presence of a potentially interfering extreme reflectance value in the surroundings of the symbol.

NOTE The same notation is used to specify a minimum grade that is required in an application as is a grade that is obtained by measuring a symbol in accordance with this standard. For example, an application standard may specify a symbol quality requirement as 1.5/05/660 and this would be met by a measured grade of X.X/05/660 as long as X.X is a number that is greater or equal to 1.5. However, this requirement would not be met by 2.0/10/660 nor 3.0/05/W nor 3.5/05/660/30.

6 Measurement methodology for two-dimensional multi-row bar code symbols

6.1 General

The evaluation of two-dimensional multi-row bar code symbols shall be based on the application of the methodology of ISO/IEC 15416, modified as described in 6.2.2 or 6.3, and if appropriate for the symbology, on the application of the additional provisions described in 6.2.3, 6.2.4 and 6.2.5, to derive an overall symbol grade. Ambient light levels shall be controlled in order not to have any influence on the measurement results. The symbol shall be scanned using the light wavelength(s) and effective aperture size specified in the appropriate application standard. When performing a measurement, the scan lines should be made perpendicular to the height of the bars in the start and stop characters and should as far as possible pass through the centres of rows in order to minimise the effect of cross-talk from adjacent rows. In the case of area imaging techniques, a number of scan lines, perpendicular to the height of the bars and sufficient to cover all rows of the symbol, shall be synthesised by convolving the raw image with the appropriate synthetic aperture.

6.2 Symbologies with cross-row scanning ability

6.2.1 Basis of grading

The distinguishing feature of these symbologies is their ability to be read with scan lines that cross row boundaries. Symbologies of this type, at the date of publication of this International Standard, also share the feature that the start and stop patterns (or equivalent features of the symbol, e.g. the Row Address Patterns of MicroPDF417) are constant from row to row, or the position of only one edge in these patterns varies by no more than 1X in adjacent rows of the symbol. These symbologies shall be graded in respect of:

— Analysis of the scan reflectance profile (based on ISO/IEC 15416) (see 6.2.2)

— Codeword Yield (see 6.2.3)

— Unused Error Correction (see 6.2.4)

— Codeword print quality (see 6.2.5)

6.2.2 Grade based on analysis of scan reflectance profile

The start and stop or equivalent (e.g. Row Address) patterns of the symbol shall be evaluated according to ISO/IEC 15416. Regions with data content will be evaluated separately as described in 6.1.2, 6.1.3 and 6.1.4. Test scans of the Start and Stop patterns shall be graded using all parameters specified in ISO/IEC 15416.The effective aperture size is specified in the appropriate application standard or is the default aperture size appropriate for the symbol X dimension given in ISO/IEC 15416.

For the analysis of the scan reflectance profiles, the number of scans should be ten, or the height of the symbol divided by the measuring aperture if this quotient is less than ten. Scans should be approximately evenly spaced over the height of the symbol. For example, in a twenty-row symbol the ten scans might be performed in alternate rows. In a two-row symbol, up to five scans might be performed in each row, at different positions in the height of the bars. The symbology specification may give more specific guidance on the selection of the scans to be used.

To identify bars and spaces, a Global Threshold for each scan has to be determined. Global Threshold shall be equal in reflectance to $(R_{max} + R_{min}) / 2$, where the values R_{max} and R_{min} are respectively the highest and the lowest reflectances in the scan. All regions above the Global Threshold shall be considered spaces (or quiet zones) and all regions below shall be considered bars.

Edge locations shall be determined as the points where the reflectance value is midway between the highest reflectance in the adjoining space and the lowest reflectance in the adjoining bar, in accordance with ISO/IEC 15416.

For the evaluation of the parameters 'decode' and 'decodability' the reference decode algorithm for the symbology shall be applied.

Each scan shall be graded as the lowest grade for any individual parameter in that scan. The grade based on scan reflectance profiles shall be the arithmetic mean of the grades for the individual scans.

The measurement of bar width gain or loss may be used for process control purposes. Note that this method will not be sensitive to printing variations parallel to the height of the start and stop characters. If a full analysis of the printing process is desired, symbols should be printed and tested in both orientations.

6.2.3 Grade based on Codeword Yield

This parameter measures the efficiency with which linear scans can recover data from a two-dimensional multi-row symbol. The Codeword Yield is the number of validly decoded codewords expressed as a percentage of the maximum number of codewords that could have been decoded (after adjusting for tilt). A poor Codeword Yield, for a symbol whose other measurements are good, may indicate a Y-axis print quality problem (such as those shown in Table C.1).

Obtain a matrix of the correct symbol character values, such as would result from successful completion of the *UEC* calculations (see 6.2.4). This matrix is used as the "final decode of the symbol" used in subsequent steps to determine validly decoded codewords.

An individual scan qualifies for inclusion in the Codeword Yield calculation if it meets either of two conditions:

1) The scan did not include recognised portions of either the top or the bottom row of the symbol. At least one of the Start or Stop (or Row Address) patterns shall have been successfully decoded from that scan, together with at least one additional codeword or the corresponding second Start or Stop pattern, or Row Address Pattern.

2) The scan included recognised portions of either the top or the bottom row of the symbol. Both the Start and Stop patterns of the symbol shall have been successfully decoded from that scan.

It is important to note that an extension to the symbology's Reference Decode Algorithm is required, in order to detect and decode a pair of Start and Stop patterns when neither of the adjacent codewords is decodable. As examples, a linear search for a matching pair of PDF417 Start and Stop patterns, or a linear search for a matching pair of MicroPDF417 Row Indicator Patterns, would fulfil this requirement for scans where the Reference Decode Algorithm alone did not decode both patterns; thus this extension can qualify a scan where no codewords (other than the matched end patterns) were decoded. Note however, that a scan that contains only a *single* decoded Start or Stop pattern found by this linear search does not count as a qualified scan, if no other codewords or corresponding second Start or Stop pattern, or Row Address Pattern, were also decoded.

Decode the symbol completely and populate the symbol matrix.

For each qualified scan, compare the codewords actually decoded with the codewords in the symbol matrix and count the number of codewords that match. Accumulate the total number of validly decoded codewords, and update a count of the number of times each codeword of the symbol has been decoded and a count of the number of times each row has been detected. Also record a count of the number of detected row crossings in each scan (a crossing is "detected" when a scan line yields correctly-decoded codewords from adjacent rows).

After processing each scan, calculate the maximum number of codewords that could have been decoded thus far, as the number of qualified scans multiplied by the number of columns in the symbol (excluding the fixed patterns, such as the Start and Stop patterns of PDF417 or the Row Address Indicators of MicroPDF417).

The entire symbol shall be scanned multiple times until three conditions are met:

1) the maximum number of codewords that could have been decoded is at least ten times the number of codewords in the symbol,

2) the highest and lowest decodable rows (which may not necessarily be the first and last rows) of the symbol have each been scanned at least three times, and

3) at least (0.9n) of the codewords (data or error correction) have been successfully decoded two or more times, where n is the number of non-error-correction data codewords in the symbol.

EXAMPLE Taking a PDF417 symbol with 6 rows and 16 columns and error correction level 4, the total number of codewords is 96, of which 64 are data and 32 error correction. To fulfil condition 1, the maximum number of codewords that could have been decoded must be at least 960. To fulfil condition 3, since n is 64, at least 58 of the codewords must have been decoded twice or more ($0,9 \times 64 = 57,6$).