INTERNATIONAL STANDARD

ISO/IEC 29158

First edition
2020-12

Information technology — Automatic identification and data capture techniques — Direct Part Mark (DPM) Quality Guideline

Technologies de l'information — Techniques automatiques d'identification et de capture de données — Ligne directrice de qualité du marquage direct sur pièce (DPM)

Reference number
ISO/IEC 29158:2020(E)

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see https://patents.iec.c).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This first edition cancels and replaces ISO/IEC TR 29158:2011, which has been technically revised.

The main changes compared to the previous edition are as follows:

— inclusion of continuous grading;

— expanded grading levels for minimum reflectance (R_{target});

— inclusion of a tilted lighting and camera position;

— reorganized proposed lighting options.

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.

Introduction

Direct Part Marking (DPM) is a technology whereby, generally, an item is physically altered to produce two different surface conditions. This alteration can be accomplished by various means including, but not limited to, dot peen, laser mark, ink jetting, and electro-chemical etch. The area of the alteration is called "the mark." The area that includes the mark and background as a whole, when containing a pattern defined by a bar code symbology specification, is called "a symbol."

When light illuminates a symbol, it reflects differently depending on whether it impinges on the background of the part or on the physical alteration. In most non-DPM bar code scanning environments, light is reflected off a smooth surface that has been coloured to produce two different diffuse reflected states. The DPM environment generally does not fit this model because the two different reflected states depend on at least one of the states having material oriented to the lighting such that the angle of incidence is equal to the angle of reflection. Sometimes the material so oriented produces a specular (mirror like) reflectance that results in a signal that is orders of magnitude greater than the signal from diffuse reflectance.

In addition, from the scanner point-of-view, some marking and printing methods generate dots and are not capable of producing smooth lines. This is important for symbologies such as Data Matrix, which is specified to contain smooth continuous lines, but can be marked with disconnected dots in DPM applications.

Current specifications for matrix symbologies and two-dimensional print quality are not exactly suited to reading situations that have either specular reflection or unconnected dots or both. Additionally, symbologies specified to consist of smooth continuous lines may appear with unconnected dots. This is intended to act as a bridge between the existing specifications and the DPM environment in order to provide a standardized image-based measurement method for DPM that is predictive of scanner performance.

As with all symbology and quality standards, it is the responsibility of the application to define the appropriate parameters of this guideline for use in conjunction with a particular application.

Information technology — Automatic identification and data capture techniques — Direct Part Mark (DPM) Quality Guideline

1 Scope

This document is an engineering document intended for verifier manufacturers and application specification developers.

This document describes modifications to the symbol quality methodology defined in ISO/IEC 15415 and a symbology specification. It defines alternative illumination conditions, some new terms and parameters, modifications to the measurement and subsequent grading of certain parameters and the reporting of the grading results.

This document was developed to assess the symbol quality of direct marked parts, where the mark is applied directly to the surface of the item and the reading device is a two-dimensional imager.

When application specifications allow, this method is also potentially applicable to symbols produced by other methods. This is appropriate when direct part marked (DPM) symbols and non-DPM symbols are being scanned in the same scanning environment. The symbol grade is reported as a DPM grade rather than as an ISO/IEC 15415 grade.

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 15415, *Information technology — Automatic identification and data capture techniques — Bar code symbol print quality test specification — Two-dimensional symbols*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 and ISO/IEC 15415 and the following apply.

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

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

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

3.1
reference symbol
high-contrast printed calibration card for which results are traceable back to national or international standards and for which the supplier supplies a calibration certificate

3.2
stick
line segment comprised of image pixels that is used to connect areas of the same colour that are near to each other

4 Symbols and abbreviated terms

CM cell modulation

CC cell contrast

CMOD cell module modulation

FPD fixed pattern damage

M_D mean of the grid-centre point histogram of the dark elements

M_L mean of the grid-centre point histogram of the light elements

M_{Lcal} mean of the light lobe from a histogram of the calibrated standard

$M_{Ltarget}$ mean of the light lobe from the final grid-point histogram of the symbol under test

R_{cal} reported reflectance value, R_{max}, from a calibration standard

R_{target} measured percent reflectance of the light elements of the symbol under test relative to the calibrated standard

NOTE R_{target} is graded and reported as the parameter named “Minimum Reflectance”.

S_{Rcal} system response parameters (such as exposure and/or gain) used to create an image of the calibration standard

$S_{Rtarget}$ system response parameters (such as exposure and/or gain) used to create an image of the symbol under test

T_1 threshold created using a histogram of the defined grey scale pixel values in a circular area 20 times the aperture size in diameter, centred on the image centre using the algorithm defined in Annex A

T_2 threshold created using the histogram of the reference grey scale image pixel values at each intersection point of the grid using the method defined in Annex A

T_{min} current minimum threshold in the calculation of the optimal threshold according Annex A

T_{max} current maximum threshold in the calculation of the optimal threshold according Annex A

TCL tilted coaxial lighting and camera position

5 Overview of methodology

5.1 Process differences from ISO/IEC 15415

All parameters in the symbology and print quality specifications apply except for:

— a different method for setting the image contrast;

— a different method for creating the binary image;

— a new method for choosing the aperture size;

— an image pre-process methodology for joining disconnected modules in a symbol (where applicable);

— a different process for determining the modulation and reflectance margin parameter renamed cell modulation (CM);

— a different process for determining the symbol contrast parameter which has been renamed cell contrast (CC);

— a different process for computing FPD;

— A new parameter called minimum reflectance (R_{target}).

Axial nonuniformity, grid nonuniformity and unused error correction are applied with their continuous grading grades as defined in Annex C, so long as ISO/IEC 15415 does not provide information on continuous grading for these parameters. If/when ISO/IEC 15415 does provide continuous grading on these parameters, that information will be used. This document explains how to both specify and report quality grades in a manner complementary to, yet distinct from, the method in ISO/IEC 15415.

NOTE Annex F gives a cross reference comparison of this document to ISO/IEC15415.

5.2 Lighting

Lighting environments shall be reported according to 6.2 and 10.2. The lighting environment(s) shall be selected by the application standard in consideration of the properties of the mark and the requirements of the reading equipment and environment of the application.

5.3 Tilted coaxial lighting and camera position (TCL)

TCL is useful for DPM applications that use a geometrical mark which is peened, drilled or carved into a surface. Reading camera and unidirectional illumination are located at a coaxial position with a known fixed tilt angle and object rotation angle and position.

To read dot-peened codes, there are multiple reading setups possible. This document defines several camera and lighting setups in order to address various dot peen geometries.

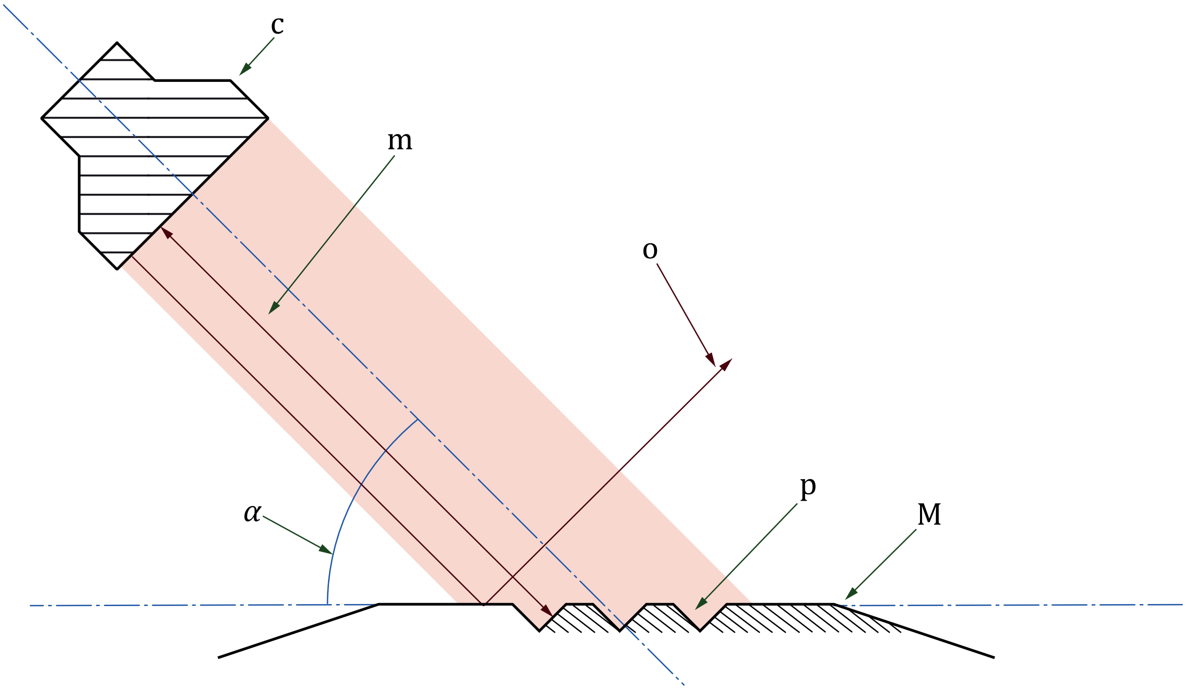
This specific TCL environment is focussing on the system response of the mark (e.g. the image a camera sees). SAE Standard AS9132[2] takes a different approach to specify the mark geometry.

Figure 1 illustrates the setup. The essential parameter is the camera reading angle. Typical camera reading angles include 30°, 45° or 60° in relation to the plane of the mark.

NOTE 1 The camera angle is defined in a compatible way to the lighting angle of ISO/IEC 15415:2011, Figure 3.

NOTE 2 Within the dot peen industry, it is common to specify the stylus angle which is twice the camera angle given in Figure 1.

NOTE 3 In practice, the condition "coaxial lighting" may be implemented by an approximate setup like a high distance ring. The light angle tolerance of ±3° should be respected.



Key

c camera and coaxial lighting

m light beam in mark is reflected to camera

o light beam outside mark is reflected away

α camera reading angle

p peened mark

M marked object

Figure 1 — Tilted coaxial lighting and camera setup

This setup is referenced by the abbreviation "TCL" in the following text.

It is not feasible to grade this setup with a camera angle of 90°. The result will not be significant for this application, as other features of the marked object are measured.

Note that a general-purpose verifier device may not cover this application, as it requires a special construction.

6 Obtaining the image

6.1 Camera position and symbol orientation

6.1.1 Symbol placement

Camera to object position is described in this subclause. By default, the horizontal and vertical axis of the symbol are parallel to a line formed by the edge of the image sensor within ±3° (i.e. nominally no rotation). This symbol orientation should be maintained unless an application specification requires or allows a different orientation. An application specification may specify a different symbol rotation. Since the symbol rotation is determined after decoding, the actual rotation angle should be reported so that the setup can be reproduced easily. In applications in which the rotation angle is specified, the rotation angle shall be reported to confirm conformance to specified requirements.

The part is placed such that the symbol is in the centre of the field of view.

6.1.2 Camera position in a 90 ° camera angle set up

The camera is positioned such that the plane of the image sensor is parallel to the plane of the symbol area. This is identical to a 90° camera angle.

6.1.3 TCL setup

Within the TCL setup, camera and symbol position differs in the following points.

— The camera is positioned in the camera angle defined by the application.

— The raw image is geometrically transformed to correspond to a test image with a virtual camera position with a 90° camera angle, as described in Annex B.

— The symbol rotation angle needs to be specified by the application and shall be respected by ± 5°.

6.2 Lighting environments

6.2.1 General

The lighting environment is specified by the application. This shall include a direction specifier or an angle or both. The format is an extension of the angle specifier used in ISO/IEC 15415. Several examples are given in the following subclauses.

6.2.2 Perpendicular coaxial (90)

The symbol is illuminated with diffuse light such that the specular reflection from the entire field of view is nominally uniform.

6.2.3 Diffuse off-axis (D)

A diffusely reflecting dome is illuminated from below so that the reflected light falls non-directionally on the part and does not cast defined shadows. This is commonly used for reading curved parts. The angle specifier shall be D.

This lighting is also called dome lighting.

6.2.4 Four direction (angle Q)

Light is aimed at the part at the given angle ±3° from the plane of the surface of the symbol from four sides such that the lines describing the centre of the beams from opposing pairs of lights are co-planar and the planes at right angles to each other. One lighting plane is aligned to be parallel to the line formed by a horizontal edge of the image sensor to within ±5°. The lighting shall illuminate the entire symbol area with nominally uniform energy. The angle specifier shall be angle "Q".

EXAMPLE 45Q (angle equal to 45°) or 30Q (angle equal to 30°).

6.2.5 Two direction (angle T)

Light is aimed at the part at the given angle ±3° from two sides. The light may be incident from either of the two possible orientations with respect to the symbol. The lighting plane is aligned to be parallel to the line formed by one edge of the image sensor to within ±5°. The lighting shall illuminate the entire symbol area with nominally uniform energy. The angle specifier shall be angle "T".

EXAMPLE 45T (angle equal to 45°) or 30T (angle equal to 30°).

Since there are two possible orientations in this setup (above and below, and left and right) the particular orientation actually used should be reported. The reporting method may be to indicate the location of the lights with respect to the symbol such as “north-south” when the light is incident from above and below the natural "top" and "bottom" of a symbol. The orientation of a symbol is known after decoding and related to the normal orientation of a symbol as specified in its symbology specification (e.g. a Data Matrix symbol's natural orientation has the solid borders on left and bottom, and for QR code the normal orientation has finder patterns in the upper left, lower left and upper right corners but not lower right corner.)

6.2.6 One direction (angle S)

Light is aimed at the part at the given angle ±3° from one side. The light may be incident from any of the four possible orientations with respect to the symbol. The plane perpendicular to the symbol surface containing the centre of the beam is aligned to be parallel to the line formed by one edge of the image sensor to within ±5°. The lighting shall illuminate the entire symbol area with nominally uniform energy. The angle specifier shall be angle S. Since there are four possible orientations in this setup, the particular orientation of the incident illumination should be reported based on the symbol orientation determined after decoding, with respect to the symbol's normal orientation (see 6.2.5). For example, if a symbol is upside down, and the illumination is incident from below the symbol, such that the illumination is actually oriented toward the "top" of the symbol, then the incident light should be reported as "North".

EXAMPLE 45S (angle equal to 45°) or 30S (angle equal to 30°).

6.2.7 TCL Setup

TCL setup uses coaxial light at the camera reading angle. Light is aimed at the camera reading angle with a tolerance of ±3°. The lighting shall illuminate the entire symbol area with nominally uniform energy.

Typical lighting setups are 30° (30CS), 45° (45CS) or 60° (60CS). The angle specification has an added "C" to indicate the coaxial camera position.

NOTE A camera angle of 90° is not a TCL setup (not tilted). In consequence, a specification of "(90CS)" is not allowed.

6.3 Image focus

The camera is adjusted such that the symbol is in best focus.

6.4 Depth of field

Non-planar surfaces or a TCL setup may require a depth of field range. The condition given in ISO/IEC 15415:2015, 7.3.3 should be fulfilled for the whole depth of field range.

6.5 System response adjustment and reflectance calibration

System response recording is a task performed prior to the use of an instrument. It shall be repeated in regular intervals together with the regular adjustment of an instrument.

Capture an image of the reference symbol (test code on a calibration card, see 3.1). On such a card, a symbol which achieves a SC grade of 4 shall be used. Using an aperture size of 80 % in relation to the test code module size, sample the centre of every element in the symbol including quiet zone and and set the system response so that the mean of the light elements is in the range of 70 % to 86 %, nominally 78 %, of the maximum grey scale, and the black level (no light) is nominally equal to zero. The system response is the nominally linear relationship between the reflectivity of the target and the pixel intensity values in the image as a result of several factors (e.g. shutter speed, imager sensitivity, f-stop, gain, illumination intensity). This procedure requires the ability to adjust at least one of these factors in order to adjust the system response.

Record the system response as the reference system response (S_{Rcal}) and record M_{Lcal}.

NOTE This procedure is not used for lighting configuration 90.

7 Verifying a symbol

7.1 Initial image reflectance

7.1.1 General

The reference grey scale image is created by the following steps.

7.1.2 Initialize aperture size

The minimum and maximum X-dimensions should be specified by the application standard and used by the verifier in this and subsequent steps. Set the aperture to 0,5 of the minimum X-dimension of the application and apply it to the image to create a reference grey scale image.

7.1.3 Create initial histogram

Create a histogram of the reference grey scale pixel values in a circular area 20 times the aperture size in diameter, centred on the image centre, and find the Threshold, T_1, using the algorithm defined in Annex A.

The threshold divides the histogram into two portions: a portion below the threshold which contains dark pixels and a portion above the threshold which contains light pixels (called the “light lobe”).

NOTE If the circular area of 20 times of the aperture size is larger than the field of view of a real device, then the area is limited by the field of view.

7.1.4 Compute mean

Compute the mean of the light lobe.

7.1.5 Optimize image

Adjust the system response by taking new images and repeating steps 7.1.2 and 7.1.3 until the mean of the light elements is 78 % reflectance of the maximum grey scale. A tolerance of ±8 is acceptable for the mean value of the light elements. This results in a range from 70 % to 86 % for system response.

7.2 Obtaining the test image

7.2.1 Matrix symbologies

Matrix symbologies are specified in different appearances. Some are specified to consist of separate, unconnected dots. The reference decode of such symbologies takes care of handling these separated dots. Other symbologies are specified to consist of continuous connected matrix cells. Some marking technologies are not capable of producing such symbols with smooth, continuous lines. Therefore, they appear also with unconnected dots (e.g. if marked by a dot peen process). In this specific case the code image is pre-processed to connect the unconnected dots (see Annex D). After this pre-process the standard reference decode algorithm is applied.

Once the grid of the symbol is determined, the location information is transferred to the evaluation of the reference grey scale image and subsequent processing occurs using the reference grey scale image.

7.2.2 Binarize image

Compute a reference grey scale image using the current aperture size. Using T_1, binarize the entire image.

