Competence Guide
Direct Part Marking

SICK
Sensor Intelligence.

COMPETENCE GUIDE
DIRECT PART MARKING

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CONTENT

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DIRECT PART MARKING

The triumphant advance of the barcode began over thirty years ago. Since then, it has revolutionized every form of merchandise and logistics management. The original idea – in keeping with the theme of black on white – was to print the barcode on a label. The major advantage is the simple, high contrast design of the code. When something is printed well, it can be read well too.

Things have changed dramatically, since there is an increasing demand for technology that allows individual components and modules, such as circuit boards or mechanical parts of a car or aircraft, to be provided with a permanent, identifiable marking. The development of 2D matrix codes and the rapid performance improvements in image processing enabled new, label-free direct marking methods to be used, such as dot peening, laser marking, or ink jet marking. In other words, direct part marking (DPM). Compared with the traditional label, DPM survives the most unfavorable of production and operational processes, as well as environmental factors, whilst inadvertently preventing product piracy. This opens up new possibilities for the user in terms of tracing individual components or modules, since they possess a mark that is permanent, identifiable and practically indestructible. To ensure the required levels of process reliability and productivity in factory automation, it must be possible to read codes quickly and dependably. Only when all factors – coding, marking, and reading – are combined properly the user can benefit from successful direct part marking.

This “Competence Guide” provides an introduction to the world of direct part marking (DPM), and presents the principles of coding, the techniques used in direct marking, and the key requirements for reliably reading DPM codes in factory automation.

As one of the world‘s leading manufacturers of intelligent sensors and sensor solutions, SICK is a strong and competent partner when it comes to direct part marking. By collaborating with other leading marking technology producers, SICK offers a worldwide network of partners for the systematic design and efficient application of direct part marking.

THE SYSTEM TO SUCCESS

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- Code Structures
- Code Types
- The Data Matrix Code

MARKING

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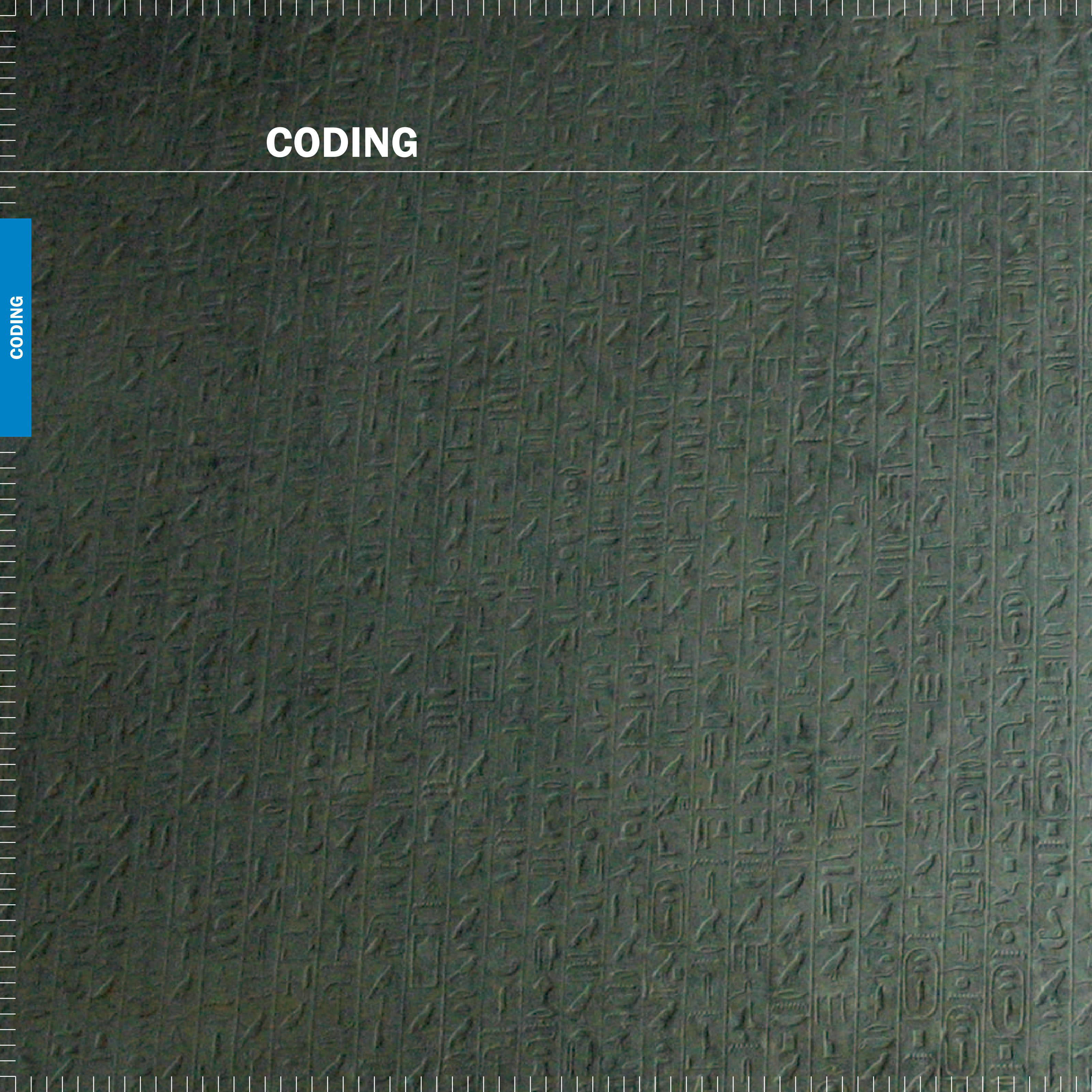
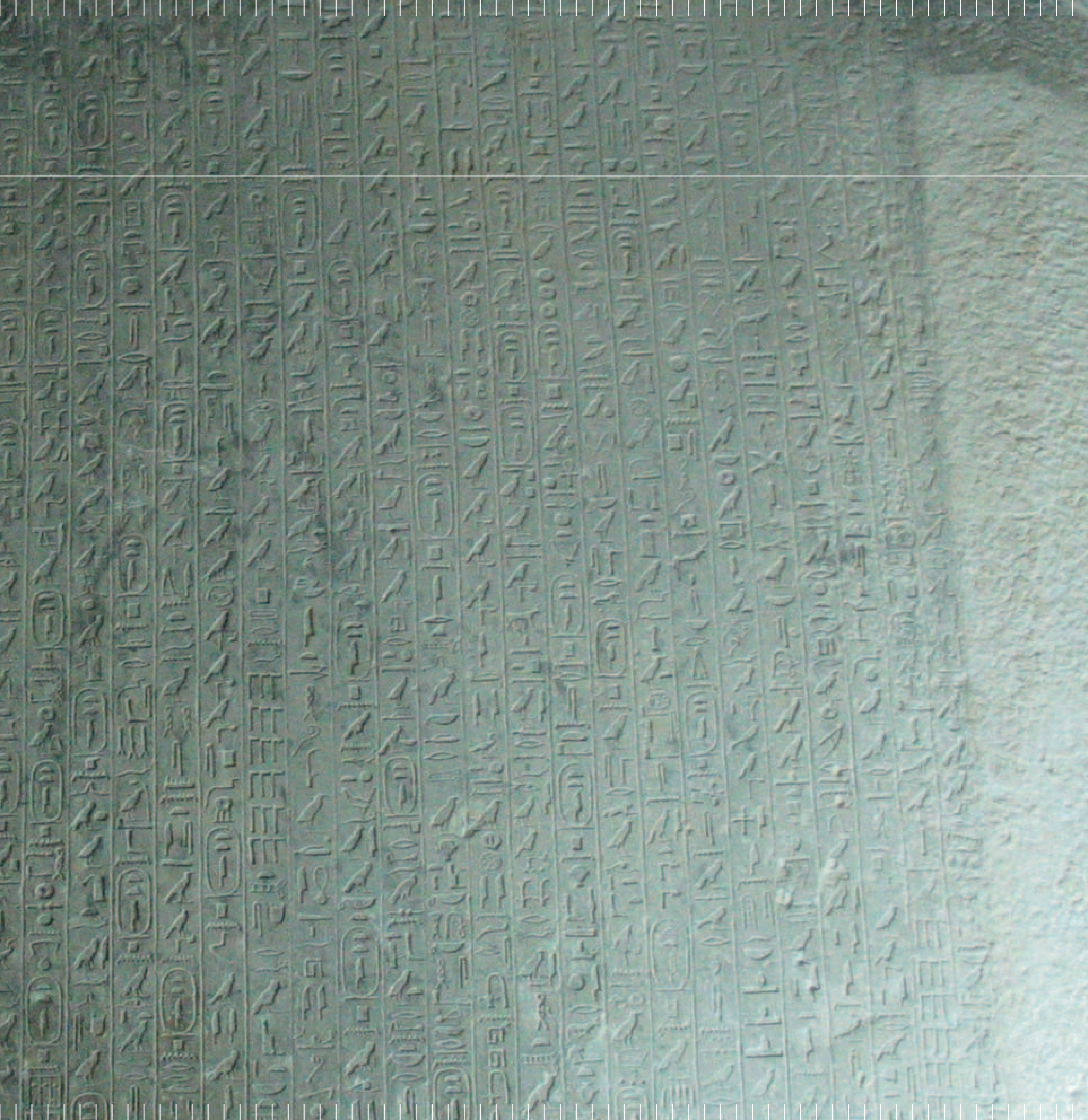
- Ink Jet
- Dot Peening
- Electrolytic Chemical Etching
- Positioning the Code Mark

READING

- Readers
- Illuminating the Object
- Verifying Data Matrix Codes
- Factors for Successful Reading

CODING



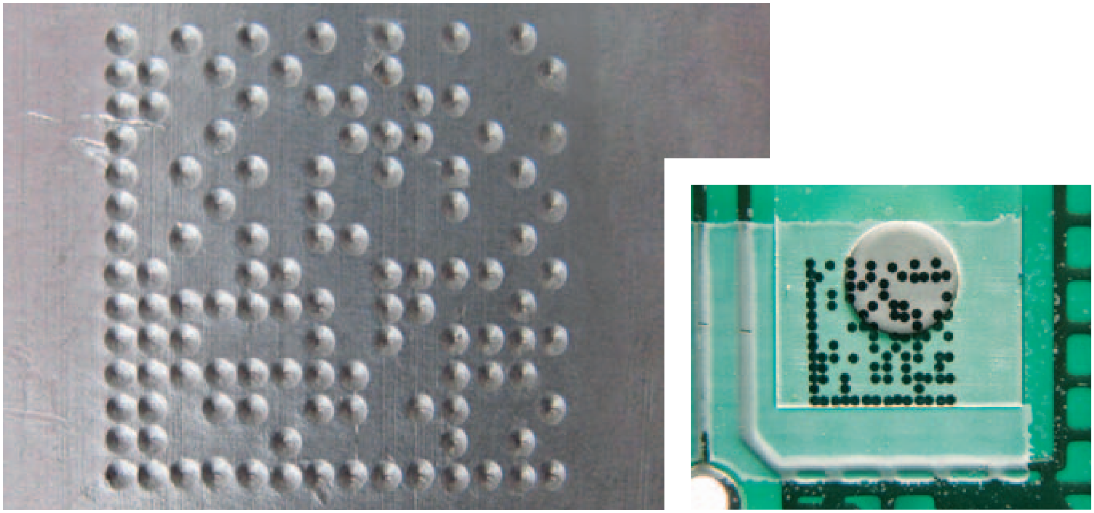


CODING

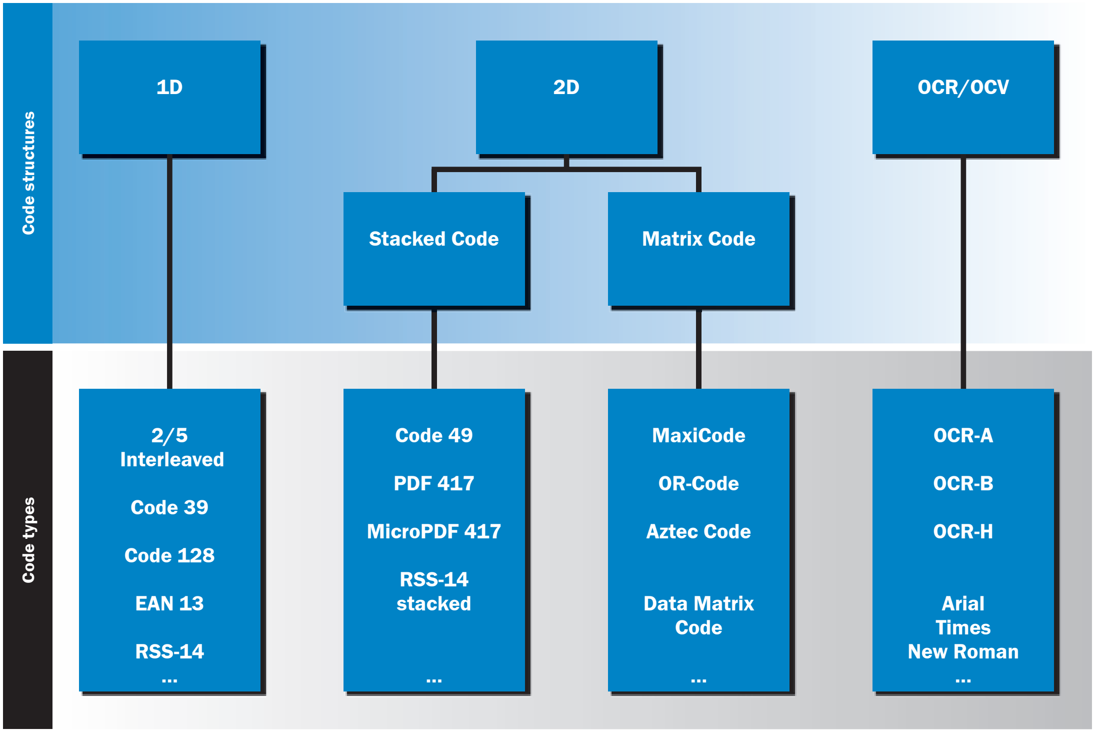
The range of established codes available today is extremely broad. This means that the user can choose from many different options but is also confronted with the problem of finding the right code:

- ***Which code is best suited to my particular application?***
- ***What is the difference between 1D and 2D, or between Code 39, 2/5 Interleaved, and Data Matrix?***

This chapter aims to provide an introduction to the different code structures and types, as well as their range of benefits, in order to help the user to choose the right code. In addition, the fundamental aspects of the different code structures are examined to prevent elementary errors when the code is "created". Because the better the code suits the particular application and the higher the quality of the applied code, the higher the reading performance, which in turn helps the application to run better.



Dot peening on steel and ink jet printing on plastic



Overview of code structures with respective code types

CODING

1. Code Structures

Codes for industrial use are divided into three code structures. Each of these code structures can be assigned to particular code types, which in turn each display special properties and are used in certain fields of application and industry.

Depending on the code structure, all code types have a distinctive structure and certain properties that are important for stable code reading.

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1.1. 1D Codes

The first one-dimensional code structures to become available were barcodes.

Basic components of a 1D code with quiet zones, start character, the actual information, and stop character

The barcode comprises elements – bars (dark) and spaces (light) – aligned in parallel. The information contained in the code is defined via the width of the bars and spaces and their sequence. The minimum module (bar) width can be chosen freely, but must be suitable for the readers used. The standard module width ranges from 0.15 to 1 mm. The barcode also has a start and stop character at the beginning and end of the code. These characters consist of a defined sequence of bars and spaces that depends on the code type. They ensure that the code type is recognized. An element known as a quiet zone precedes the start character and follows the stop character. This quiet zone must contain no interference structures. This is the only way to ensure a clear distinction between the code and the background, thereby making the code identifiable. The quiet zone should be approximately ten times the width of the narrowest module.

Almost all code types can be extended to include check digits, which are used to verify the plausibility of the read result. The check digit is calculated from the read result of the barcode according to a defined formula and compared with the check digit value that was included in the barcode. If both values match, the content of the code is output. If they do not match, the reader outputs the result “no read”. This avoids any misinterpretation and, consequently, any misinformation.

1.2. 2D Codes

In comparison to one-dimensional barcodes, two-dimensional codes allow the density of information to be increased substantially. A distinction is made between two code structures for two-dimensional codes: stacked codes and matrix codes.

1.2.1. Stacked Codes

Stacked codes consist of several rows of 1D codes stacked one on top of the other, each of which is delimited by its own start and stop characters that span the entire height of the code. As with barcodes, the start character must be preceded and the stop character followed by a quiet zone. The start and stop characters also define the code type in the case of stacked codes.

Basic components of a stacked code with quiet zones: start and stop characters and the encoded information

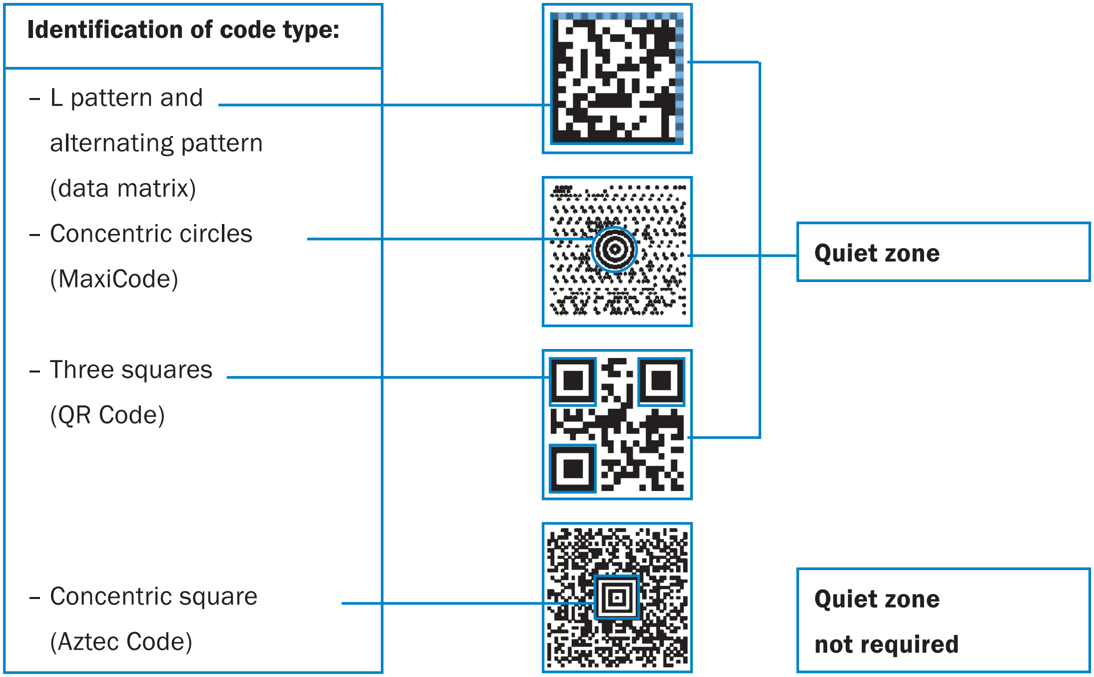
CODING

1.2.2. Matrix Codes

Since the density of information continued to be insufficient for many applications, matrix codes were developed.

Compared with bar and stacked codes, matrix codes comprise light and dark elements that often take the form of square dots. These are aligned with each other in a normatively defined manner. The dots may be of any size, but must be suitable for the reading and marking technology deployed. The dots are usually between 0.1 and 0.6 mm in size.

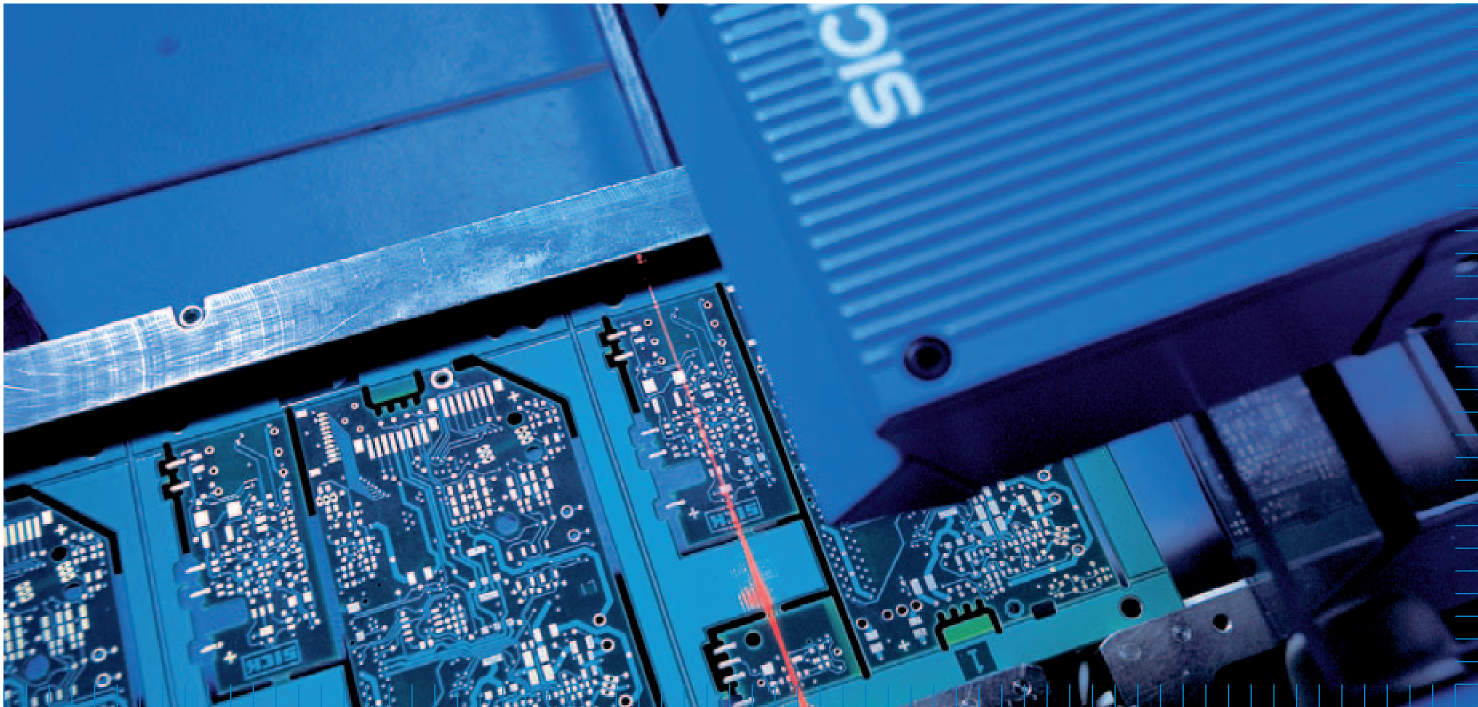
Basic components of a 2D code



Matrix codes consist of a data field and additional, code-dependent finder patterns. These finder patterns allow the code on an object to be located and identified.

Matrix codes also usually require a quiet zone. This surrounds the entire code and is needed so that the code can be uniquely identified. In comparison with 1D codes, the quiet zone is relatively small because it only corresponds to the width of a matrix code dot.

Most 2D codes contain redundant data. Compared with the check digits in 1D codes, the redundant data significantly improves reading reliability because it is not only possible to verify the plausibility of the content that has been read. Part of the encoded information can be reproduced using mathematical algorithms, and this information remains intact even if part of the code is destroyed. This heightened data security has made direct marking possible in particular with the data matrix code.



CODING

1.3. OCR/OCV

OCR and OCV are not codes. OCR and OCV are procedures whereby human readable, alphanumeric characters are recognized by an automatic identification system.

1.3.1. OCR

OCR (Optical Character Recognition) is the automatic recognition of printed characters or entire text strings by means of optical scanning. Special fonts were originally developed and standardized for this purpose, for example OCR-A (DIN 66008, ISO 1073-1); OCR-B (ISO 1073-2); OCR-H (DIN 66225).

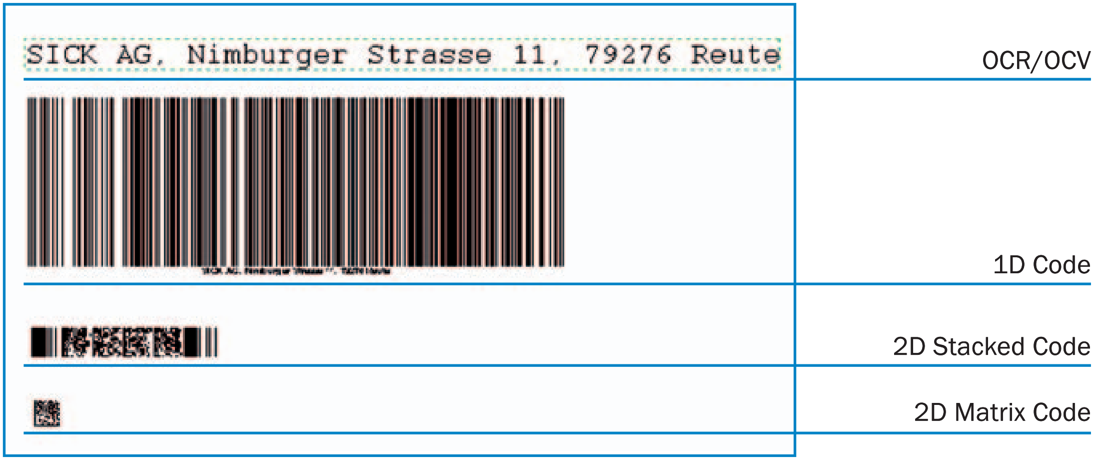
More effective reading systems and improved algorithms now also allow "normal" printer fonts and even handwritten characters to be recognized (for example, in mail distribution). To enable the text to be read, the respective font must first be "taught in". The readers can then compare the captured character structures with the structures stored in a database, and thereby recognize all known characters and output the "read" string as the reading result.

1.3.2. OCV

Unlike OCR, OCV (Optical Character Verification) does not read a text string, but instead compares a previously taught-in text with the text found on the object. This takes place via image processing algorithms that, for example, determine the total number of pixels or recognize the contours. The result of OCV is, therefore, either a “TRUE” or a “FALSE” with a supplementary evaluation of the correctness, quality, and readability of the string.

1.4. Information Density

The following comparison between the different sizes of the code structures (using selected code types as examples) clearly illustrates the extent to which the information density of the individual structures varies.



The data content and bar width or dot size is identical in all codes.

CODING

CODING

1.5. Choosing the Right Code Structure

The following key questions are important when choosing the right code structure:

How much space is available for the code on the object to be identified?

How much and what data is to be encoded?

How can I apply the code to the object? What carrier material do I use in my application?

Is there a risk that codes will be obstructed by a contaminant?

Does the code have to be human readable?

Which industries do I deliver my products to, and do they have any specific requirements?

Are there any basic conditions for applying the codes?

How much can I spend on my reading system?

Depending on the space available on the object, different code structures are better suited than others, since the information densities vary. For example, 2D matrix codes can accommodate large amounts of information on a small space.

Depending on the volume of data, that is the number of characters, certain code structures are more suitable than others because the code dimensions of code structures with a low information density do not fit into the viewing window of the reader.

Matrix codes can be applied directly to the object, while barcodes should first be applied to an additional carrier material to ensure that they can be read reliably.

Depending on check digits and redundant data, some code structures can be read more reliably than others. Ambient factors such as contamination or the possibility of the code being destroyed must be taken into account.

In the aviation industry, for example, cableforms are identified by humans. Additional optical characters or OCR/OCV can, therefore, be useful here.

Industry-specific requirements and standards are common in certain industries. The user must consider these when choosing the code. A list of the currently applicable norms and standards can be found in the chapter “Standards”.

Typical conditions include production speeds, distance between object and reader, and required reading field size.

The code structure defines the requirements for the reading system, and thereby also the price. Furthermore, the marking method to be used also determines the running expenses and investment costs.

CODING

Selection table to aid the decision-making process and comparison of the individual code structures along with their most important criteria

Code Structure		Cost of Reader	Space Require-ments	Information Density	Reading Reliability	Human Readability	Industry
Optical Char-acters (OCR)		High	Very high	Low	Low	Yes	Pharmaceutical, food, automotive, aviation, and aerospace industries
1D		Low	High	Average	Average	With additional optical characters	Consumer goods industry, parcel and postal services
2D	Stacked Codes	Average	Average	High	Average	No	Pharmaceutical and consumer goods industries, parcel and postal services
	Matrix Codes	Average	Low	Very high	High	No	Automotive, electronic, pharmaceutical, aviation, aerospace, and food industries

2. Overview of Code Types

Each code structure is divided into different code types. Each code type has its own special characteristics, as well as benefits or drawbacks for particular applications.

2.1. 1D Code Types

Important characteristics of 1D codes include the usable character set, intrinsic reliability, data volume and space requirements.

Some code types only support numeric characters, while others can encode alphanumeric or even the complete ASCII character set. Intrinsic reliability is a measure of how vulnerable to mis-

interpretation the code is. In theory, the amount of data a linear code can contain is unlimited. In practice, however, it is extremely limited because the code requires sufficient space in the reader‘s reading window and on the object itself.

	Code Name	Character Set	Intrinsic Reliability	Space Requirements	Standard	Application
1234567890	2/5 Interleaved	Numeric	Low	Low	ISO/IEC 16390	Parcel and postal services
DPM	Code 39	Alpha-numeric	Average	High	ISO/IEC 16388	Parcel and postal services
123456789012	Code 128	ASCII	High	Low	ISO/IEC 15417	Parcel and postal services
1 234567 890128	EAN 13	Numeric	High	Low	DIN EN 797	Parcel and postal services
	RSS-14	Numeric	High	Very low	ISO/IEC 24724	Consumer goods industry

Comparison of standard 1D code types

CODING

2.2. 2D Stacked Codes

The individual types of stacked code differ with regard to their data capacity and are used in very specific industries. They play a somewhat subordinate role in comparison to matrix codes.

Comparison of the most prevalent 2D stacked codes

	Code Name	Max. Number of Characters				Symbol Size (Rows)	Standard	Area of Application
		Numeric	alpha-numeric	ASCII	ISO			
	Code 49	81	49	49		2–8	ANSI/ AIMBC6	Photography industry
	PDF 417	2710	1850	1400	1108	3–90	ISO/IEC 15438	Parcel and postal services
	Micro-PDF 417	366	250	180	150	4–44	ISO/IEC 24728	Parcel and postal services
	GS1 DataBar stacked	14				2	ISO/IEC 24724	Consumer goods industry

2.3. 2D Matrix Codes

Of all the different code types available, matrix codes offer a particularly high data capacity and information density. Thanks to their special finder patterns, it is comparatively easy to differentiate between them. Various code types have already become established and recognized as standards in certain industries.

Comparison of the most prevalent 2D matrix codes

	Code Name	Max. Number of Characters per Data Type				Symbol Size (Dots x Dots)	Special Features	Standard	Area of Application
		Numeric	alpha-numeric	ASCII	ISO				
	Maxi-Code	138	–	93	93	28,14 x 26,65 mm	Finder pattern: round bull's eye, fixed symbol size, hexagonal dots	ISO/IEC 16023	Transportation logistics (parcel service providers)
	QR Code	7089	4296	–	2953	21 x 21–105 x 105	Finder pattern: three squares, can also encode Japanese Kanji characters	ISO/IEC 18004	Electronics, automotive (mainly in Asia)
	Aztec Code	3832	–	3067	1914	15 x 15–151 x 151	Finder pattern: square-shaped bull's eye, does not require quiet zone	ISO/IEC 24778	E-Ticketing, transportation logistics
	Data Matrix ECC200	3116	2335	1982	1556	10 x 10–144 x 144; 18 x 8–48 x 16	Finder pattern: L pattern, rectangular symbols also possible	ISO/IEC 16022	Electronics, automotive, aviation, pharmaceutical, and food packaging

CODING

3. The Data Matrix ECC200 Code

The Data Matrix ECC200 has become the most established of the matrix codes. It is the most commonly used code across almost all branches of industry worldwide. The Data Matrix ECC000 was developed in 1989 and continuously optimized up until 1995 to become today's Data Matrix ECC200 standard. The name "ECC200" signifies the use of the Reed-Solomon algorithm for error correction. Thanks to the high level of process reliability it offers, it has become established as the standard, thus ensuring uniform data communication worldwide.

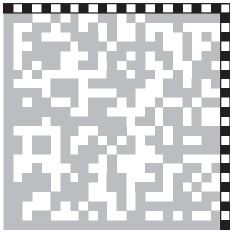
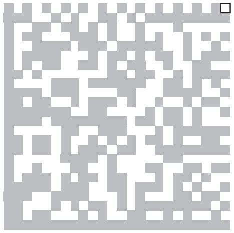
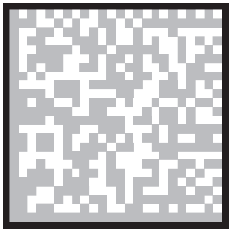
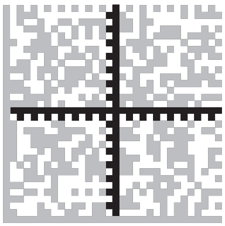
Key features of the Data Matrix ECC200:

- Worldwide standardization
- Easy to generate
- Wide variety of possible marking methods (laser, dot peening, ink jet, etc.)
- High reading reliability on the basis of the error correction algorithm used
- Low space requirements
- Maximum data capacity
- Small quiet zone

CODING

3.1. Code Elements and Composition

Component	Description
	Black and white elements of the code are referred to as dots. Each dot represents one bit, whereby a light dot corresponds to a binary “0” and a dark dot a binary “1”. The dots may be of any size, but must be suitable for the reading and marking technology used. The smaller the dot, the greater the demands on the marking devices and readers. Dot sizes from 0.1 to 0.6 mm are currently in widespread use. A clear contrast between the light and dark dots in the code is very important to ensure stable reading.
	The encoded data is contained within the **inner field/data field**.
	The **L pattern** is part of the finder pattern for determining the code type and is made up of dark dots. It is required to identify the code in the image, its distortion, and to determine the dimensions of the code. As defined in ISO/IEC 16022, the L pattern must be marked without gaps and span the entire height and width of the code.
	The **alternating pattern** (alternating white and black dots) is another part of the finder pattern. It is used to determine the code type, dot size, and symbol size of the code.

Component	Description
	The **symbol size** depends on the volume of data in the code. It is determined by counting all black and white dots along both dimensions – (the finder pattern‘s dots are also included here). The Data Matrix ECC200 consists exclusively of an even number of dots. In this case, 24 x 24 dots. Further information can be found in chapter 3.2.
	The **white corner** in the top right is the classifying characteristic of the Data Matrix ECC200. Data Matrix 000-140 have a black corner in this position.
	The code is surrounded by a **quiet zone** (shown in black in this illustration to make it more visible). Its width and height should at least match the size of a single dot; a wider and taller quiet zone is, however, advisable to provide a high level of process reliability. As defined in ISO/IEC 16022, no interference structures whatsoever may be located within this zone (for example, components on the object, other codes, or optical characters).
	**Alignment patterns** are required as an additional guide for symbols of 32 x 32 or greater, and are generated automatically when coding takes place.

CODING

3.2. Data Capacity and Symbol Size

Data Matrix ECC200 is very flexible in terms of the volume of data it can accommodate. The number of characters that have to be encoded affects the symbol size (number of dots along both dimensions) of the code. The following table describes the normatively defined sizes of square symbols and their respective maximum data volumes.

Data capacity of square Data Matrix ECC200 in relation to symbol size (number of dots in rows and columns) and data type used

Symbol Size																								
Rows	10	12	14	16	18	20	22	24	26	32	36	40	44	48	52	64	72	80	88	96	104	120	132	144
Columns	10	12	14	16	18	20	22	24	26	32	36	40	44	48	52	64	72	80	88	96	104	120	132	144
Data Capacity																								
Numeric	6	10	16	24	36	44	60	72	88	124	172	228	288	348	408	560	736	912	1152	1392	1632	2100	2608	3116
Alphanumeric	3	6	10	16	25	31	43	52	64	91	127	169	214	259	304	418	550	682	862	1042	1222	1573	1954	2335
Byte	1	3	6	10	16	20	28	34	42	60	84	112	142	172	202	278	366	454	574	694	814	1048	1302	1556

Example

Symbol size:	36 x 36 Matrix
Data content:	SICK 1D and 2D Competence Guide
Data capacity:	Maximum 172 numeric characters (numbers) or maximum 127 alphanumeric characters (numbers and letters)

The 24 square symbol sizes are accompanied by a further six rectangular variants. These variants are often used on curved objects. Applying them along the longitudinal axis reduces code distortions and the effects of reflectance. When a 1D barcode is converted to a data matrix code, a rectangular form can also be appropriate because the space available is already rectangular given the geometry of the 1D barcode.

Symbol Size						
Rows	8	8	12	12	16	16
Columns	18	32	26	36	36	48
Data Capacity						
Numeric	10	20	32	44	64	98
Alphanumeric	6	13	22	31	46	72
Byte	3	8	14	20	30	47

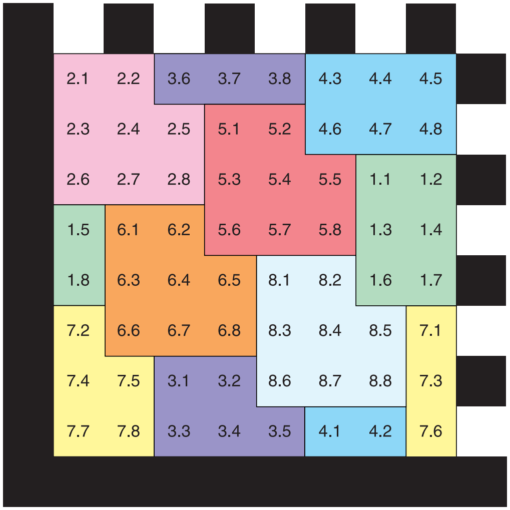
Data capacity of rectangular Data Matrix ECC200 in relation to symbol size (number of dots in rows and columns) and data type used

Example

Symbol size: 8 x 18 Matrix

Data content: DPM

Data capacity: Maximum 10 numeric characters (numbers)
Maximum 6 alphanumeric characters (numbers and letters)



Data is stored in the data matrix code according to a particular pattern. Each dot represents one bit; the dark dots are interpreted as “1” and the light dots as “0”. Eight bits together make up one byte and are also referred to as a “code word” for the data matrix code. A code word must contain a minimum of one alphanumeric and two numeric characters.

The graphic illustrates how data is distributed in the code. The eight bits of each byte are shown in the same color.

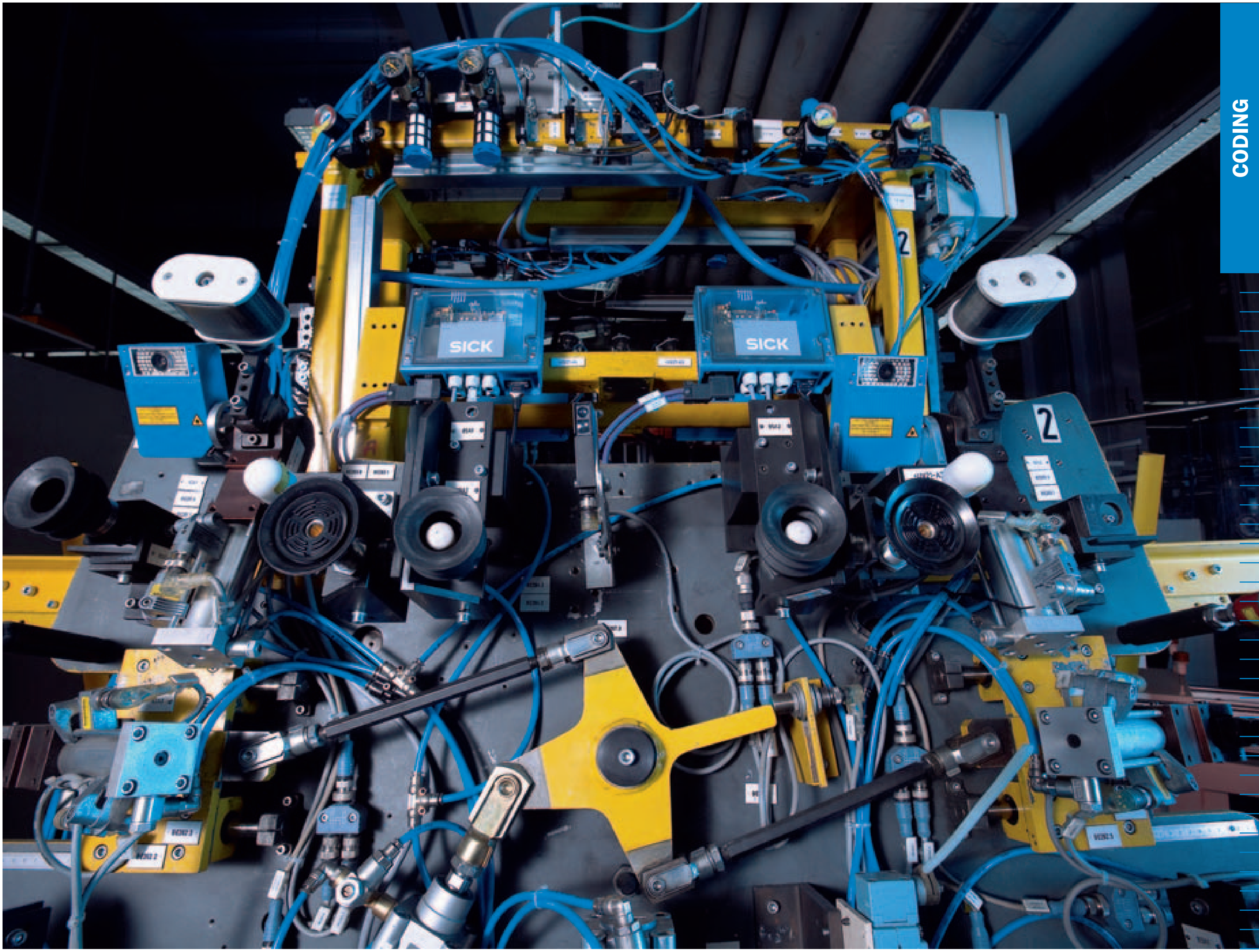
3.3. Data Redundancy

The user data is encoded with the Reed-Solomon error correction algorithm. This algorithm, which has its roots in the aviation and aerospace industries, was originally used to transmit data securely for satellite communication. The underlying principle of the Reed-Solomon error correction algorithm is that the required data content is accompanied by further, redundant data. If the data is destroyed, this redundant data makes it possible to calculate the lost data. This error correction algorithm constitutes a very effective compromise. On the one hand, additional data is placed in the code to ensure higher security, while on the other hand, the space required still remains very low.

Data redundancy in the Data Matrix ECC200 ensures the highest possible levels of reading reliability and process stability, even when up to 62 % of the code has been destroyed or become contaminated (depending on symbol size).

3.4. Code Creation

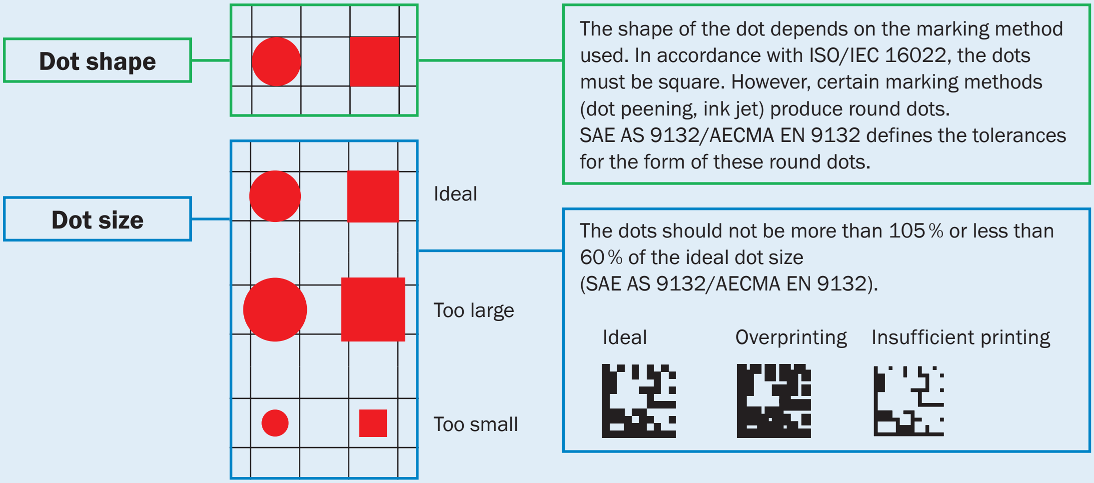
Code label software is used to encode the user data in a code. The encoding process is fully automatic, and the resulting code can be identified with every reader. The data can either be entered manually, for example using the keyboard, or obtained from a database.

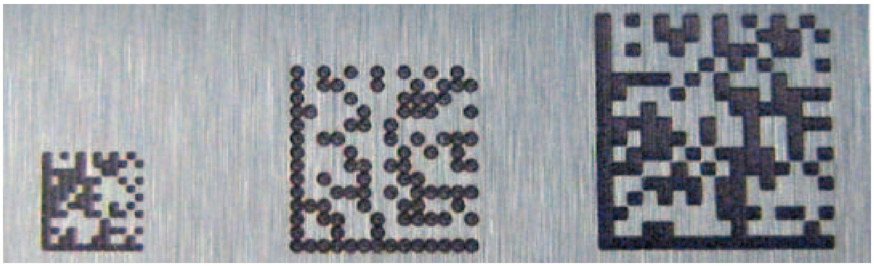

SICK
SICK

CODING

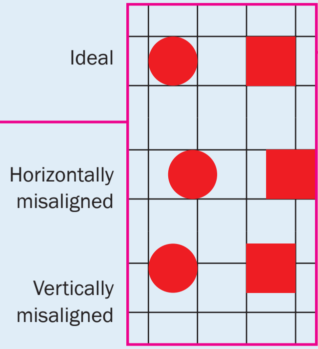
3.5. Quality Characteristics of Code Creation

In addition to the basic elements of data matrix codes, further recommendations apply that have a positive effect on process reliability. The higher the quality of the code, the higher the process reliability. These recommendations can be found in different standards and regulations (see appendix).



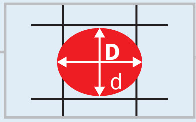


The dots should deviate as little as possible from the theoretical reference grid, that is, the ideal dot position or dot center. A deviation is referred to as a **dot center offset**.
A deviation of 0–20 % is classed as tolerable (in accordance with SAE AS 9132/AECMA EN 9132).



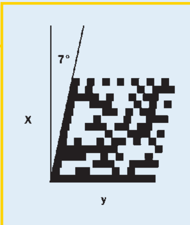
Dot position

Depending on the marking method, it may only be possible to create round dots. Threshold values also exist for deviations from the ideal circle to ensure that the code can be read reliably.
The difference between D and d should not exceed 20 % of the dot size.



Dot ovality

Distortion of the code should be avoided. Distortions can occur during marking (if the code is applied to a curved surface or if the object moves), or during reading (if the reader tilts excessively). Ideally, the angle between the X and Y axes should be 90°. A deviation of 7° is tolerable (in accordance with SAE AS 9132/AECMA EN 9132).



Distortion

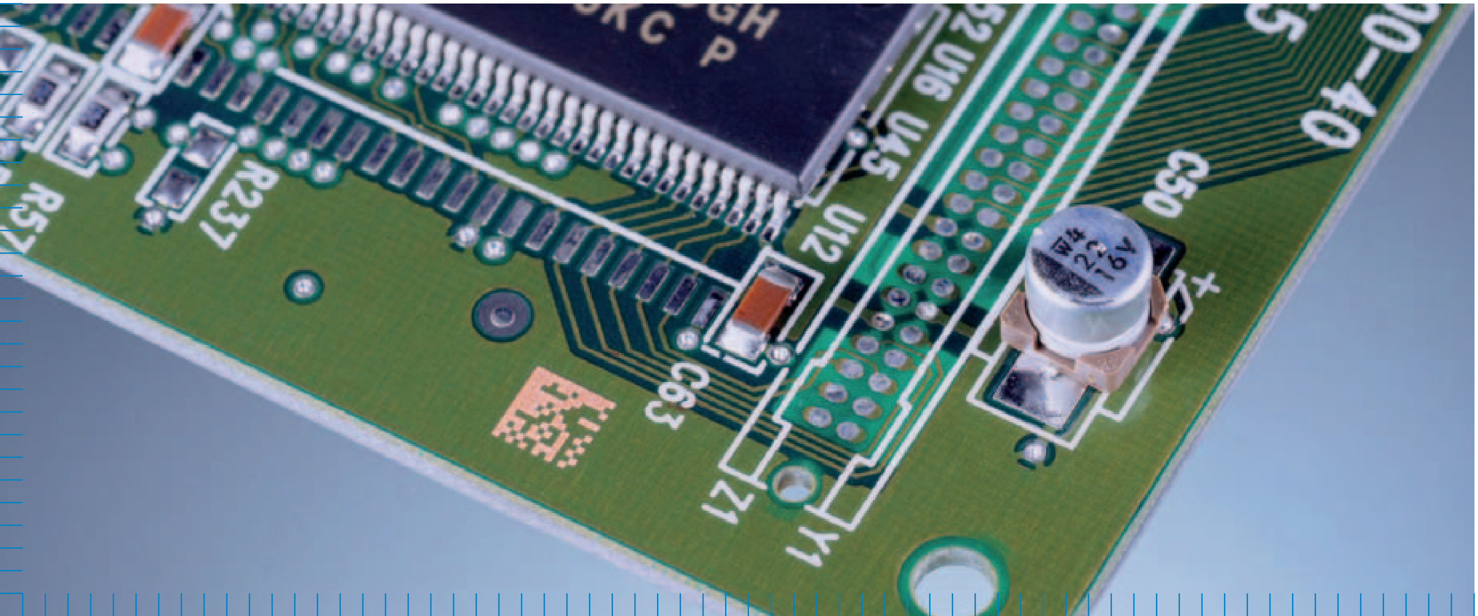
MARKING

MARKING

Once the right code has been chosen, the most suitable method of marking the object must be selected. Essentially, there are two different methods:

- **Marking with labels:**
  A code is printed on a carrier material – either paper, plastic, or metal – and this is then affixed to the object to be marked. Advantages: simple, established process, code contrasts are very high and stable.
- **Direct part marking (DPM):**
  Direct marking of an object without a carrier material, today known as direct part marking (DPM), offers a range of advantages: durability, robustness, flexibility of the marking, prevention of product piracy.

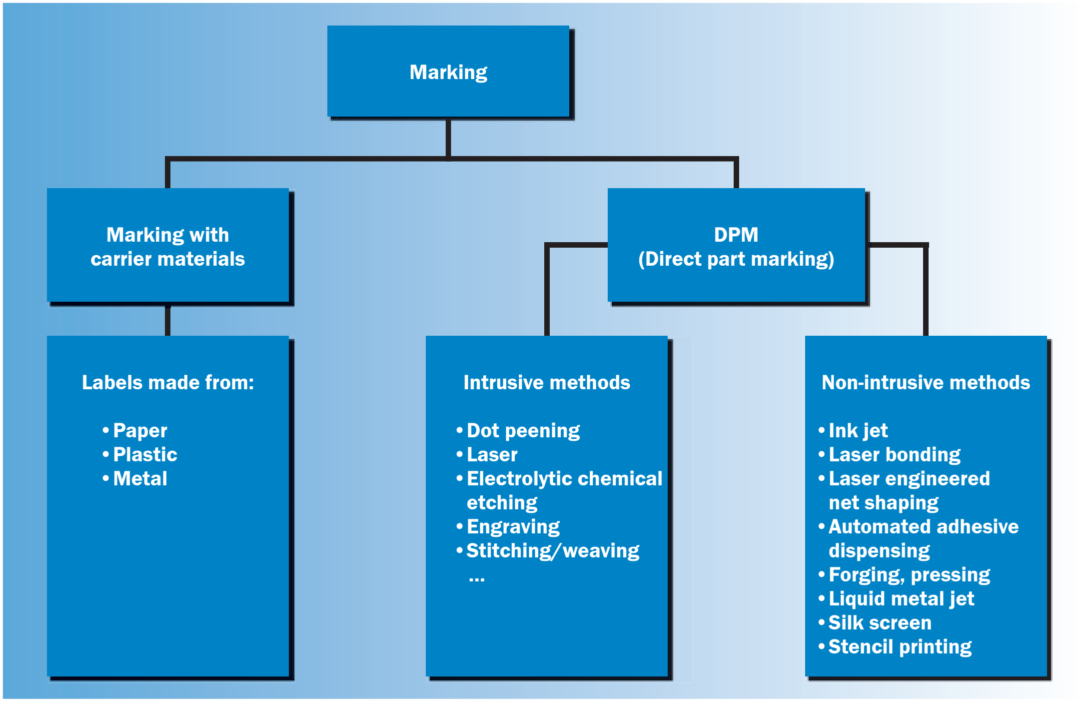
In many cases, the advantages of direct marking outweigh those offered by the use of carrier materials. Direct marking, however, depends to a great extent on the material the object, or rather the surface of the object, is made from. This can pose new challenges for the user.



1. Overview of Marking Methods

In the case of direct marking, methods are divided into the categories intrusive and non-intrusive:

- Intrusive methods alter the surface of the object through abrasion, stripping, vaporizing, burning etc.
- Non-intrusive methods provide the object with an additional layer containing the code.



Overview of marking methods

MARKING

MARKING

The most common methods in use in the market today are explained in detail in the sections that follow. To provide an initial overview, the following table compares criteria that are key to selecting the marking method. The main criteria are the material to be marked, flexibility of the process, arising costs, speed, throughput, and linked to this, the possible level of automation of the marking procedure.

	Laser	Ink jet	Dot peening	Electrolytic chemical etching
Variety of materials that can be marked	High	High	Average	Low
Flexibility (complex object surfaces, distance be-tween object and marking device, options for marking)	High	Average	Average	keine
Investment/initial outlay	High	Average	Low	Low
Required equipment	Low	Average	Average	Average
Possible level of automation (achievable number of units, speed of marking procedure)	High	High	Average	Low
Type of marking method (non-contact = object does not need to be secured mechanically with contact = object needs to be secured mechanically)	Non-contact	Non-contact	With contact	With contact
Abrasion resistance of mark	High	Low	High	High

A wide range of materials can be marked directly, depending on the marking method. The peculiarities of each material must be taken into account. SICK marking technology partners (see page 110 et sqq.) provide support in finding the right solution.

		Aluminum	Copper	Titanium	Iron	Steel	Gold	Silver	Magnesium	Ceramic	Glass	Synthetics*	Teflon	Cloth	Wood
Laser	Gas laser										•	•	•		
	Solid-state laser	•	•	•	•	•	•	•	•	•		•		•	•
Ink jet		•	•	•	•	•	•	•	•	•	•	•		•	•
Dot peening		•	•		•	•	•	•				•			
Electrolytic chemical etching		•	•	•	•	•	•	•	•						
		Metals								**Non-metals**					

* For example, POM, PUR, PP, PE, PS, PC, PBT, PA, PVC, ABS

In this chapter, the four most common marking methods used in the automotive, electronics, and aviation industries are discussed in more detail:

- Laser
- Ink jet
- Dot peening
- Electrolytic chemical etching

First, the general principles and the way in which the mark is applied are described for each of the methods. Various product categories and marking types are then examined in relation to the respective marking methods. The concluding evaluation of pros and cons combined with a few insider tips make it possible to preselect the most suitable marking method.

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2. Laser

2.1. Laser Marking Functionality

When an object is marked using laser, the interaction of material and the laser's wave length – known as the absorption behavior – creates a contrast on the object. This can be achieved by ablating the material or altering its properties. The way in which the material reacts to laser depends on the material itself, as well as the machining parameters configured for the laser. The machining parameters must be carefully matched to the respective material and are normally determined in application tests. Changes to the composition of the material can prompt a change in the contrast of the mark. Laser marking can be used to apply barcodes, 2D codes, and optical characters to objects.

2.2. Laser Types

Laser types are distinguished according to the optically active medium in which the laser beam is created. The standard laser types for marking objects include:

- Gas laser, for example CO_2 laser
- Solid-state laser, for example Nd:YAG laser

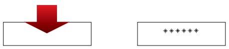
  with subcategory fiber laser, for example FAYb laser.

Gas lasers are particularly well-suited to marking synthetic materials and glass. Metals, on the other hand, can only be marked in this way in certain cases. Solid-state lasers are ideal for marking almost any type of material (metals, ceramic, synthetic materials). Fiber lasers have the benefit of being very effective and small in terms of overall size with a long service life.

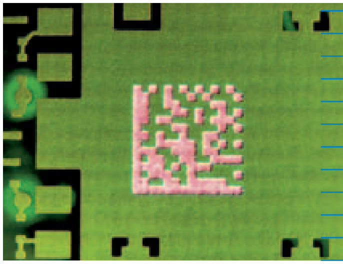
2.3. Laser Marking Methods

Laser marking uses different marking methods. The following table shows the marking methods available in relation to the material to be marked.

The seven marking methods

Marking Methods	Graphical Depiction	Principle	Materials
Ablation		Ablation of surface coatings	Coated metals such as anodized aluminum, lacquered materials, or composites such as circuit boards
Engraving		The material vaporizes partially, engraving is itself colorless, a contrast is created by the reaction with atmospheric oxygen.	Metals, ceramics, and some synthetics
Tempering		Local heating of the material to below its melting point. The resulting tempering colors are stable up to approx. 200 °C.	Certain metals, for example titanium
Change in color/ bleaching		Changes to or destruction of certain additives (such as filler materials or chromophoric pigments) in the material.	Predominantly synthetics
Foaming/ carbonizing		Local smelting, this causes a foaming of the material.	Certain synthetics
Smelting/thermal ablation		Changes to surface reflectance through foaming of the material.	Metals, synthetics, and glass
Inner-engraving		Creation of microcracks in the material.	Glass and plexiglass

Ablation of layers on circuit boards



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The type of marking can be configured or optimized with the following parameters:

- Laser power
- Operating speed
- Pulse repetition frequency

2.4. Evaluation of Laser Marking Systems

In addition to the high level of precision, the key feature is the broad spectrum of markable materials using a wide range of laser and marking types. Regardless of whether the material is metal, synthetic, ceramic, or glass, laser offers the maximum possible level of flexibility. This flexibility translates into a high degree of automation in the production process in almost all industries.

Advantages of Laser Marking

Advantages	Customer Benefits
High level of precision of markings	Stable reading and high level of process reliability
Many materials can be marked	High degree of flexibility
High marking speeds	Fast processes
Almost no operating resources necessary	Low maintenance costs

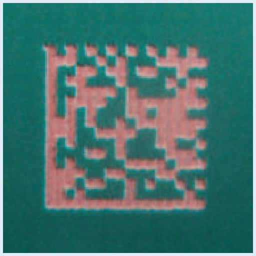
Disadvantages of Laser Marking

Disadvantages	Example Impact
High investment costs	From € 20,000 to € 50,000
Adherence to safety regulations	Additional investment costs; Safety officer required
Material exposed to thermal stress	Potential for microcracks in metals/ceramics

2.5. Quality Characteristics of Laser Marking

The primary goal of laser marking is to achieve a high level of contrast between the marking and the background. The following examples provide an overview of well, acceptably and poorly marked codes.

Examples of Good Codes



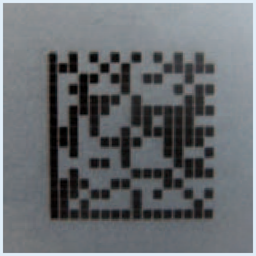
Laser type: Nd-YAG

Object: Circuit board

Code quality: Very good contrast through ablation of plastic layer down to copper. L pattern and dots are geometrically very cleanly lasered. Degree of fill of dots is near ideal.

TIP: Ageing/oxidation of copper (black coloring) causes considerable worsening of contrast.

Corrective measures: Avoid boards being stored for long periods before identification process, or apply a transparent protective coating.



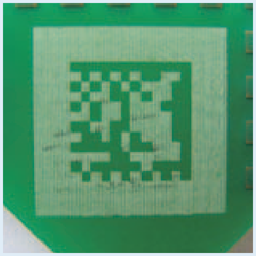
Laser type: Nd-YAG

Object: Metal

Code quality: Very good contrast between code and background, dots are square in form and almost 100 % filled.

TIP: To achieve a perfect code, close the minimal gaps in the L pattern.

MARKING



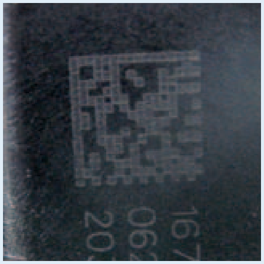
Laser type: CO_2

Object: Circuit board

Code quality: Very good contrast between code and background, dots are correctly arranged geometrically. Square dots would render the reading process more stable.

TIP: Avoid handling/touching the code, since this considerably reduces code contrast.

Example of Acceptable Codes



Laser type: CO_2

Object: Plastic

Code quality: Readable code despite poor contrast between dots and background.

TIP: Readability can be increased by changing the marking parameters of the laser, or by using an additive in the plastic to increase the contrast.

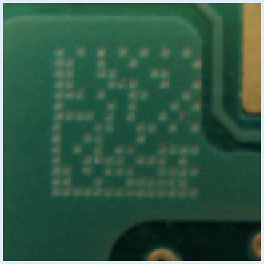
Examples of Bad Codes

Laser type: Nd-YAG

Object: Metal

Code quality: Code unreadable due to poor contrast between dots and surface of the material. Interfering structures (scoring) on the metal surface lower the quality of the code.

TIP: Cleaning the surface helps to produce a consistent contrast between code and background and to suppress interference structures.



Laser type: CO_2

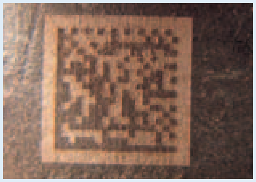
Object: Circuit board

Code quality: Poor contrast and interference in quiet zone, therefore unreadable.

TIP: Change position of code. The copper under the thin layer of plastic reflects the light from the chosen form of illumination through the plastic. This means that there is virtually no contrast, even though it would at first appear so to the human eye.

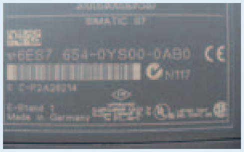
MARKING

Cleaning Rough and/or Reflective Surfaces



To achieve an optimum contrast between code and background, the laser not only creates the actual code but also modifies its background. This minimizes interference structures, such as those that occur in cast materials or polished, shiny surfaces. This is known as cleaning.

Additives in Synthetic Materials with Poor Contrast



It is difficult to achieve good results when laser marking certain synthetic materials. By introducing additional filler materials, additives, or chromophoric pigments into the source material, the absorption behavior and thereby the contrast of the marking can be improved. Frequency multiplication further improves the absorption behavior of the laser and achieves a higher-contrast mark.

3. Ink Jet

3.1. Ink Jet Functionality

With the ink jet marking method, color pigments that are applied to the object create the code. To achieve this, ink is sprayed directly onto the object. The solvent it contains evaporates and leaves behind the pigment as the code. Specially configured inks are available for each material. They are developed by the manufacturers to ensure the best possible adhesion of the ink to the material.

3.2. Ink Jet Types

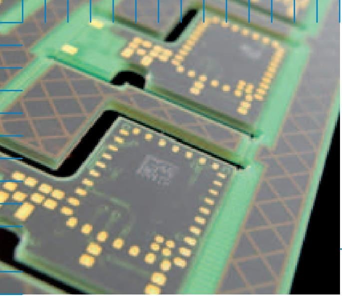
Two ink jet marking methods are available:

- Drop-on-demand method
- Continuous method

The continuous method is used predominantly for data matrix codes. With this method, single droplets of ink are pressed through a jet, electrically charged, and deflected to the exact position on the object via two electrically charged deflection plates. The ink droplets can only be deflected in one dimension, which means that the object or print head is also required to move. Ink droplets that are not needed for the mark are extracted before they reach the object and returned to the ink cycle.

The main difference between ink jet printers lies in the number of jets and their diameters. Small jet diameters result in a mark with a higher resolution. A greater number of jets per print head enables higher marking speeds.

Industrial ink jet printers can operate with greater distances between the print head and the object. They are considerably more flexible because the object does not need to be moved into



Ink jet on a circuit board

MARKING

position (similar to paper feed on a printer); they can instead be adapted to suit the material and object to be marked.

3.3. Evaluation of Ink Jet Marking Systems

In addition to low initial outlay, the key feature here again is the wide spectrum of markable materials. Inks to achieve optimum adhesion are available for each material. This means that nearly all materials can be marked: metals, ceramics, glass, or synthetics. Problems arise only in the case of Teflon and materials that contain silicon, as the ink does not adhere well.

Additional flexibility is achieved through high marking speeds associated with a high degree of automation, enabling ink jet marking systems to be used in almost all industries.

Advantages of Ink Jet Marking

Advantages	Customer Benefits
Low investment costs	From € 5,000 to € 20,000
Many materials can be marked	High degree of flexibility
High marking speeds	Fast processes

Disadvantages of Ink Jet Marking

Disadvantages	Example Impact
Achieves only average code quality precision	More difficult to align the identification process with the marking process
Low wear resistance when subjected to mechanical demands	Printed code may be mechanically damaged or destroyed during subsequent processing: instable process
Every material requires its own, specially configured ink	High operating costs
Object must be clean	Additional cleaning costs when objects/ materials are changed, or for release agents, such as oils and greases
Marking head and object required to move	Additional investment outlay, operating resources

3.4. Quality Characteristics of Ink Jet Marking

The contrast between the marking and the background also determines the readability of the code in the case of ink jet marking. The following examples provide an overview of marked codes that are good, acceptable, and poor.

When ink jet printers are used, it is important to ensure that the ink dots are correctly positioned geometrically and do no run or smudge. Achieving a sufficient level of contrast between the code and background is also crucial in the case of ink jet marking.

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Example of Good Codes

Object: Circuit board

Code quality: Very good contrast between code and white marked background. The black dots are positioned very accurately and the degree of fill is very good despite their round form. This means that the L pattern is fully coherent.

Examples of Acceptable Codes

Object: Circuit board

Code quality: The code can be read easily and contrasts well with the white base coat of the background.

TIP: A slight deviation of the position of the dots from the ideal (dot center offset) would minimize the gaps in the L pattern (see page 33, Dot Center Offset) and increase readability.

Object: Metal, curved surface

Code quality: Readable code. Despite distortion caused by the curved surface, the degree of fill and the contrast are sufficient.

TIP: Reduce gaps and distortions to optimize readability.

Examples of Bad Codes

Object: Metal

Code quality: Code unreadable because the ink has run or the surface is too rough. The dots are blurred and the L pattern is destroyed.

TIP: Choose an ink with greater adhesion, consider polishing/burnishing the surface.

Object: Circuit board

Code quality: Code unreadable with red illumination of reader because contrast is too poor.

TIP: Mark the background of the code white or use white lighting.

4. Dot Peening

4.1. Dot Peening Functionality

With dot peening, an indenting pin creates a dimple for each code dot of the data matrix code. The variation in contrast visible to the reader is achieved through the light that reflects differently on the dimples (code) and the object surface (code background). In rare cases, one code dot is represented by four dimples that are arranged extremely closely to each other. This results in larger code dots that are almost square in form.

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4.2. Dot Peening Types

A distinction is made between three different types:

- Pneumatic dot peen markers
- Electromagnetic dot peen markers
- Scribers

The following characterize the different types of dot peening in terms of handling, marking quality, and usability:

	Electric/Pneumatic Dot Peening		Scribing
Handling	Manual	Permanently installed	Permanently installed
Markable Materials	Metals (aluminum, stainless steel) Casts Graphite PVC	Metals (aluminum, stainless steel) Casts Graphite PVC	Metals and synthetics with a smooth surface
Quality of Code Marking	Average Due to manual handling and dependency on maintenance of dot peen markers	Good – average Dependent on maintenance of indenting pins	High Due to extremely accurate positioning of code dots
Area of Application	Automotive industry Aviation industry Steel industry Mechanical engineering		
Noise Exposure	High	High	Low

The following dot peening parameters are essential to achieve optimum code marking quality:

The hardness of the object defines the hardness of the indenting pin:
the harder the material, the harder the pin has to be. The upper limit of markable metals is a hardness of approximately 63 HRC.

The hardness and thickness of the object's outermost layer defines the permissible indenting force:
The indenting force must be adjusted to suit the hardness and thickness of the object material. The benefit of electromagnetic dot peen markers over pneumatic systems is that the indenting force is kept constant. Pneumatic systems often suffer from fluctuations in compressed air supply in the region of ± 15 psi. The possible or rather permissible depth of penetration depends on the thickness of the object.

In addition, the distance between the dot peen marker and the object significantly affects the penetration depth – the greater the chosen distance, the deeper the indentation/larger the individual code dot. All in all, the penetration depth of the indentation has a crucial impact on how the light is reflected – a deeper indentation results in the code being read more effectively.

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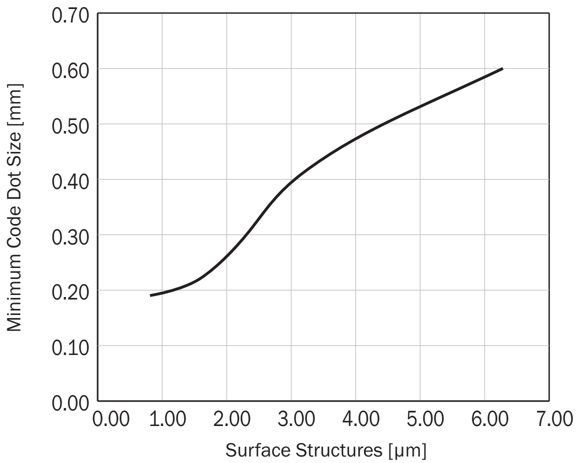
The surface finish defines the diameter of the indenting pin:

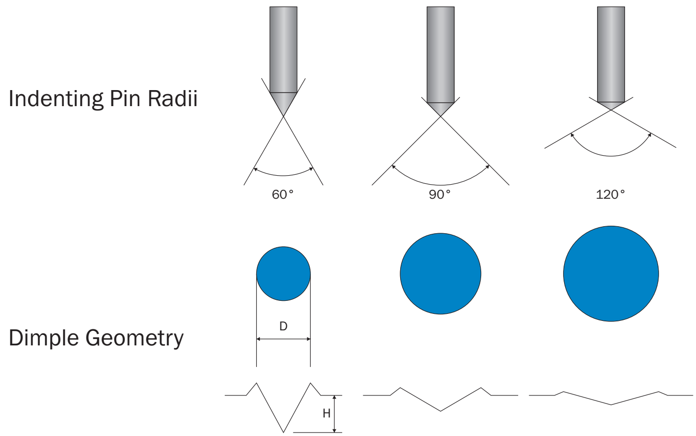
The rougher or more course the surface, the greater the diameter of the indenting pin has to be. This ensures that a clear distinction is achieved between the code dot and object background.

Surface Structures/µm	0.8	1.6	2.4	3.2	6.3
Minimum Code Dot Size/mm	0.19	0.22	0.31	0.41	0.60



2D matrix code
on diecast casing

The thickness of the object defines the geometry of the indenting pin:
the thinner the object, the flatter the pin radius has to be.



EN 9132 specifies the following pin geometries and their use:

Indenting Pin Radius	60°	90°	120°
Diameter of Individual Code Dots	≤ 0.22 mm	> 0.31 mm	> 0.31 mm
Material Hardness	Very hard		
Object Thickness		Thin	Thin

In the case of dot peen markers and scribers, it is important to note that using the indenting pin best suited to the material, as well as properly maintaining the indenting or scribing pins are factors that have a decisive impact on the quality of code marking. The pin tips wear because they become blunt as a result of the mechanical stress. As a result, the code contrast varies.

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4.3. Evaluation of Dot Peening Systems

The ability to create what is basically an indestructible code with relatively low initial outlay constitutes the key feature of dot peening systems. In particular, the fact that the material is subjected only to mechanical stress without additional thermal or chemical stress ensures that the properties of the material remain unchanged. This quality is indispensable especially in aircraft construction.

Advantages of Dot Peening

Advantages	Customer Benefits
Low investment costs	From € 5,000 to € 10,000
High mechanical, thermal, and chemical durability of code	Traceability of product throughout entire production cycle and life cycle
Mark can be coated	Traceability of product throughout entire production cycle and life cycle
Material subjected only to mechanical stress	Physical properties of material remain unchanged
High marking speeds	Fast processes

Disadvantages of Dot Peening

Disadvantages	Example Impact
Expenditure for operating resources	Maintenance and replacement of indenting pins
Securing the object mechanically is recommended	To achieve higher and more consistent quality of code marking
Only metals and plastics with sufficient thickness are markable	Low degree of flexibility
Indenting pins wear	Increased maintenance and possible deterioration of quality of code marking and code reading in automated process

4.4. Quality Characteristics of Dot Peening

In addition to achieving sufficient contrast by choosing the right indenting pin and indenting force, the following code marking characteristics should be noted and adhered to:

- Variations in dot size: 60 ... 105 %
- Variations in dot position (dot center offset): 0 ... 20 %
- Dot ovality: < 20 %
- Perpendicular code distortion: < 7 °

Details can be found in the chapter 3.5. “Quality Characteristics of Code Creation” in the section “Coding”. The following examples provide an overview of well, acceptably and poorly marked codes:

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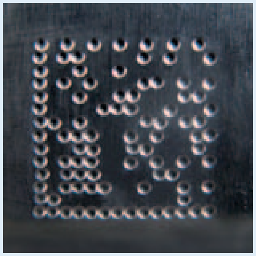
MARKING

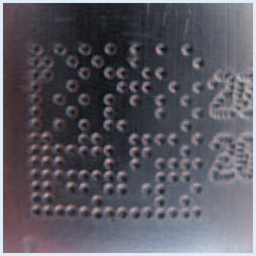
Example of Good Codes



Object: Metal

Code quality: Very good contrast between code and background, the dots all have a uniform round structure and are completely filled (100 %). The position of the individual dots does not deviate from the ideal position.

Example of Acceptable Codes

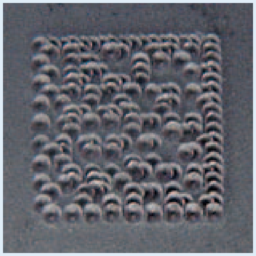


Object: Metal

Code quality: Dot geometry, position, and degree of fill near ideal.

TIP: Enlarge the quiet zone to the neighboring digit and reduce distortion to achieve a perfect code.

Examples of Bad Codes



Object: Metal

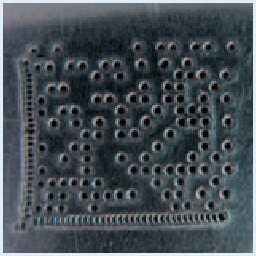
Code quality: Unreadable code because the dots overlap each other.

TIP: Poor quality might be caused by the following: indenting pin too blunt or flat, material too soft or indenting force too high, distance between indenting pin and object too great, indenting pin too hard.

Object: Metal

Code quality: Poor code caused by indenting pin being too pointed or penetration depth being too low. The dots are insufficiently filled: degree of fill < 60 %.

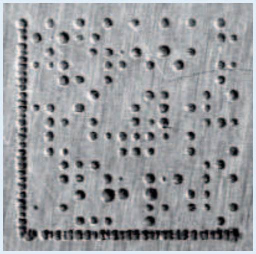
TIP: Increase indent radius.



Object: Metal

Code quality: Unreadable code caused by individual dots deviating too much from the reference pattern (dot center offset).

TIP: Indenting pin may have too much axial play, or object may be poorly secured. Differences in dot radius often occur in the first indentation if the pin pressure is not optimized. Furthermore, individual dots are missing in the alternating pattern.



Object: Metal

Code quality: Unreadable code caused by dot sizes varying too much.

TIP: Variations in indenting force, or object not secured adequately resulting in fluctuating, inconsistent distances between indenting pin and object.

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5. Electrolytic Chemical Etching

5.1. Marking Method Functionality

Electrolytic chemical etching removes individual layers of material by means of electrolysis. The first step involves applying a template of the code negative to the object. The template is then filled with an electrolyte matched to the material and pressed onto the object with a stamp. In the final step, electrolysis is initiated by applying a current to the object and stamp, prompting thin layers to be removed from the surface of the object.

Result: the positions at which the surface has been eroded reflect or absorb light to a greater or lesser extent than the untreated positions. This creates the contrast necessary to identify the mark.

5.2. Evaluation of the Marking Method

The key feature of this method is that the mark is created extremely accurately. By using the appropriate electrolyte and choosing the right “etching time”, it is possible to remove very thin layers ranging from 2.5 to 100 µm.

Advantages of Electrolytic Chemical Etching

Advantages	Customer Benefits
Very high level of precision of marks	Stable reading and processes
Low penetration depth (2.5 to 100 µm)	Impact on material is low
Suitable for extremely hard metals	High degree of flexibility
Lowest investment costs	From € 2,000 to € 5,000

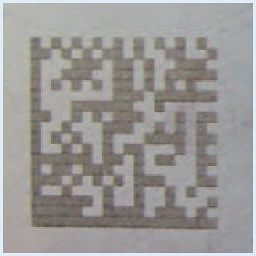
Disadvantages of Electrolytic Chemical Etching

Disadvantages	Example Impact
Only suitable for metallic, conductive materials/objects	Low degree of flexibility
High operating resource costs	A stamp is required for each code
Additional costs caused by safety and waste disposal regulations	High operating costs
Increased cleaning required to remove electrolytes	High operating costs
A stamp is required for each code	Low degree of flexibility
Cannot be automated	Only applicable for manual processes and limited number of units

5.3. Quality Characteristics of Electrolytic Chemical Etching

Indirect, multi-layer marking requires a great deal of experience to create readable codes. The following examples show well and poorly marked codes.

Example of Good Codes



Object: Metal

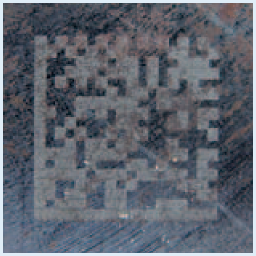
Code quality: Very good contrast between code and background, dots are square in form and completely filled (100 %).

Examples of Bad Codes

Object: Metal

Code quality: Code unreadable due to multiple interference structures.

TIP: Readability could be improved by cleaning or polishing the background beforehand.



Object: Metal

Code quality: Code unreadable due to corrosion of material.

TIP: The electrolyte was not sufficiently removed after the marking was applied.

Object: Metal

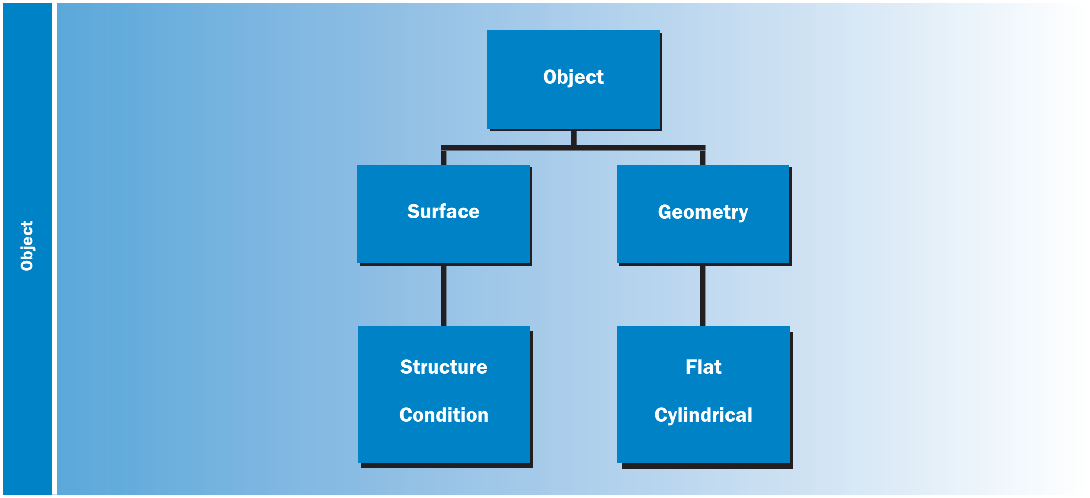
Code quality: The contrast between code and background is too poor.

TIP: Code unreadable due to electrolysis times being too short or unsuitable electrolyte being used.

MARKING

6. Positioning the Code Mark

In addition to selecting the right marking method, it is important to establish where exactly the code is to be applied to the object. The surface finish and form of the object must be taken into consideration here.

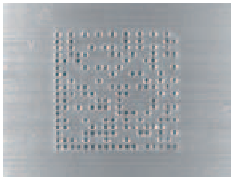


6.1. Object Surface Finish

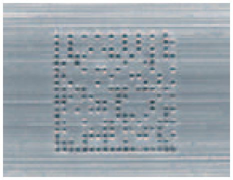
Typical examples of interference structures on surfaces include stress, scoring, or ridges on cast parts. Particularly in the case of cast parts, the code is not sufficiently discernable from the surface due to the roughness of the surface.

If surface structures are formed in such a way as to negatively impact on the readability of the code, the following methods can be applied:

- Choose an alternative marking position with fewer interference structures
- Change the illumination in order to suppress interference structures. In the case of scoring, “west-east” or “north-south” illumination can be used depending on the course of the score.

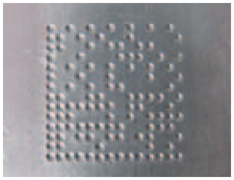


West-east illumination

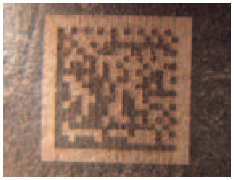


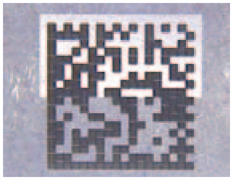
North-south illumination

- Dot peening: Every dot of a code should be many times larger than the structures on the surface.

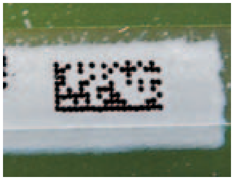


- Laser: Cleaning – polish or level the surface





- Ink jet: Coat the background in white to improve contrast.



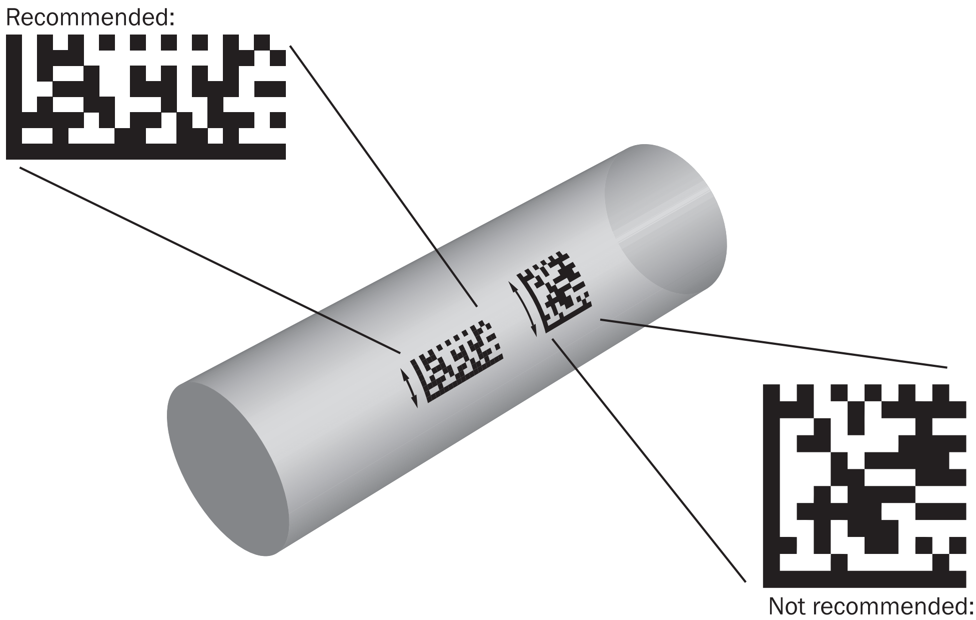
- Use labels if they are permitted in subsequent process steps.

MARKING

MARKING

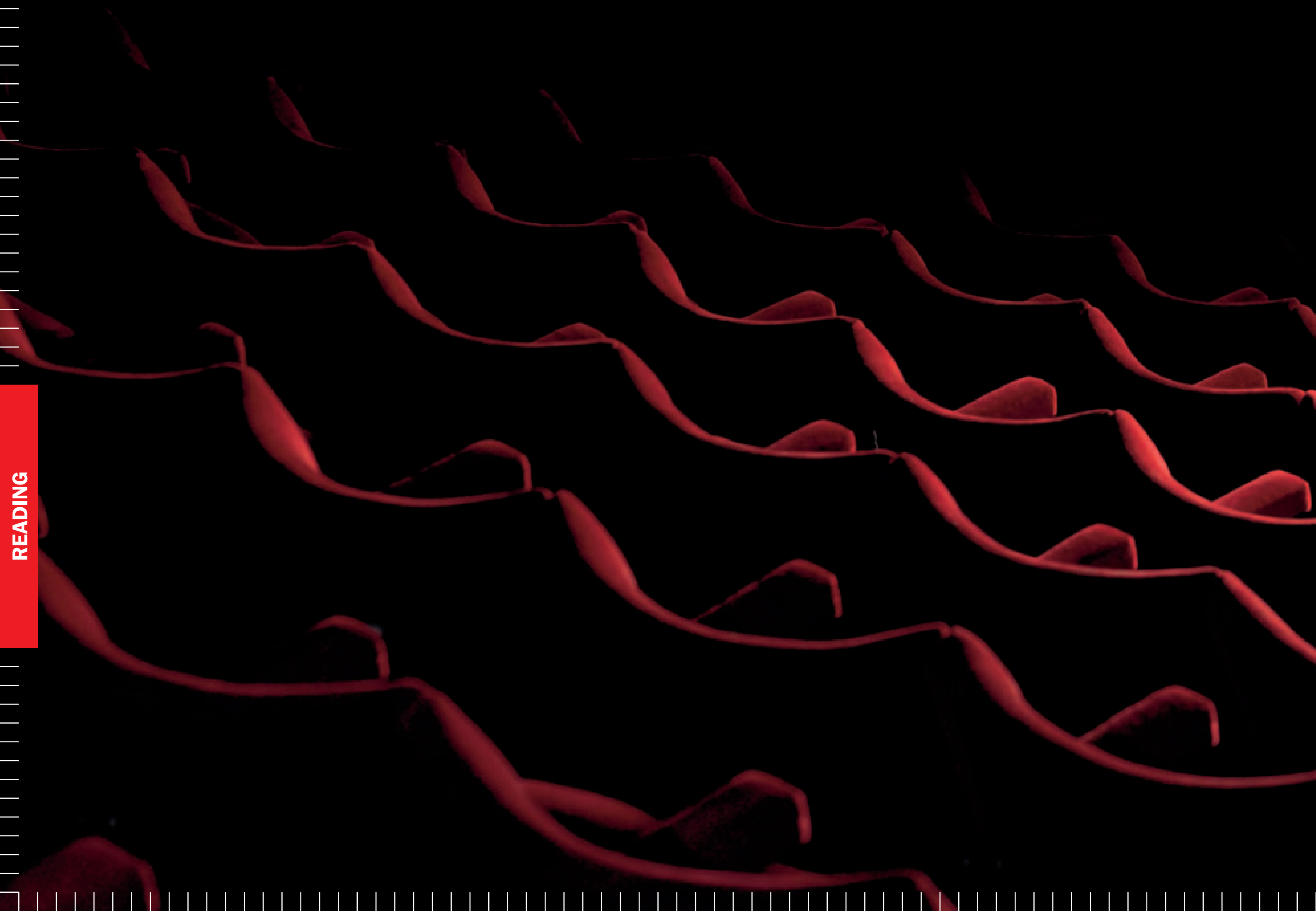
6.2. Object Geometry

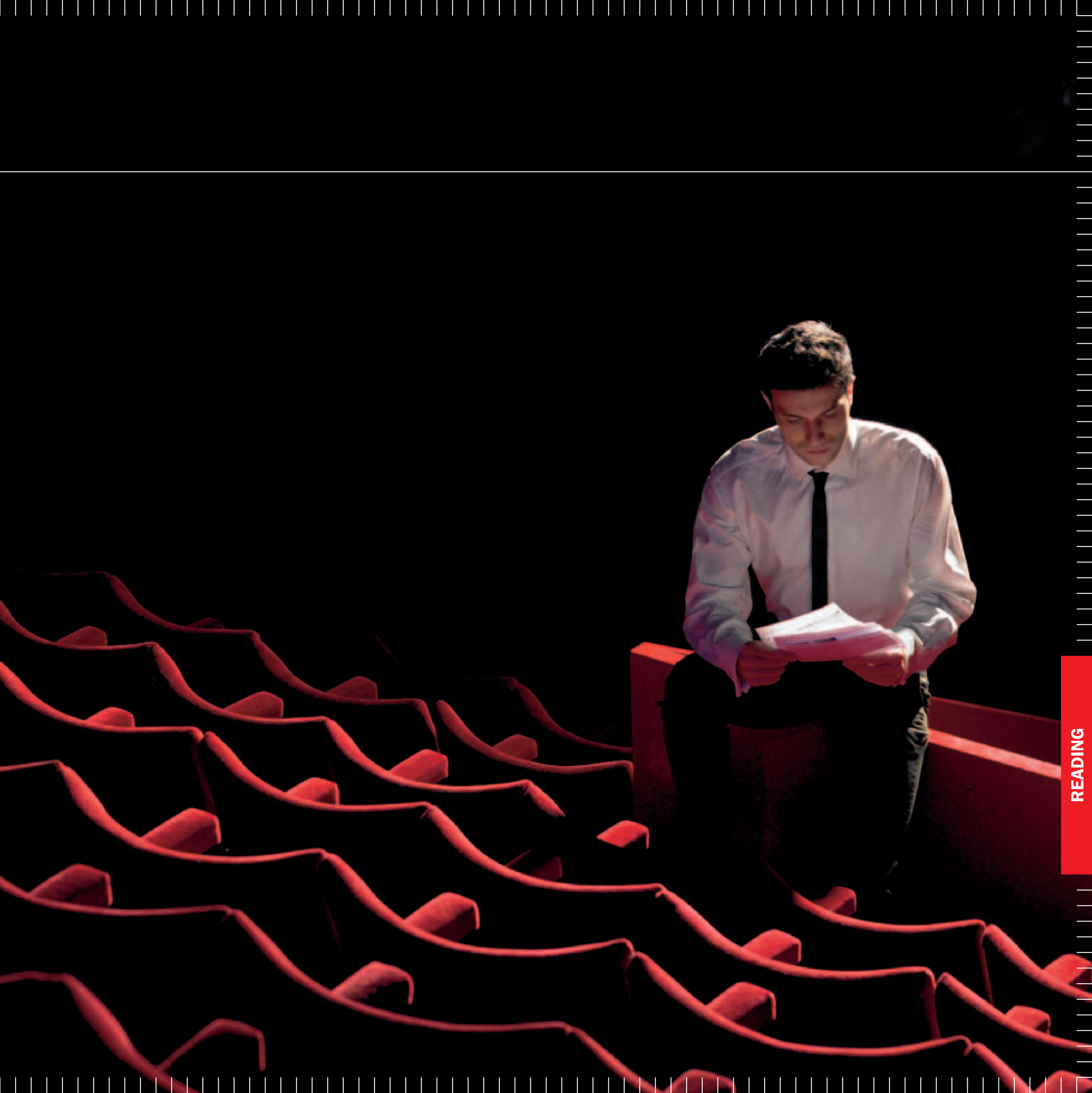
The geometry of the object has a considerable impact on the readability of a code. Distortions or suboptimal reflectance behavior can be avoided by applying the code to a flat surface. If a cylindrical surface is the only available option, its curve should be as uniform as possible.



As defined in AS 9132, the following rule of thumb applies: The data matrix code should span a maximum distance of 16 % of the diameter or 5 % of the circumference of the cylindrical body. Rectangular codes are better suited to curved surfaces because their data content is the same but with a reduced height. Stretching the code along the axis of the cylindrical body does not interfere with reading because reflections along the axis are constant.

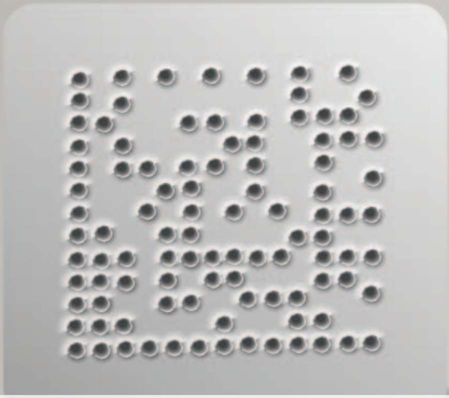
READING

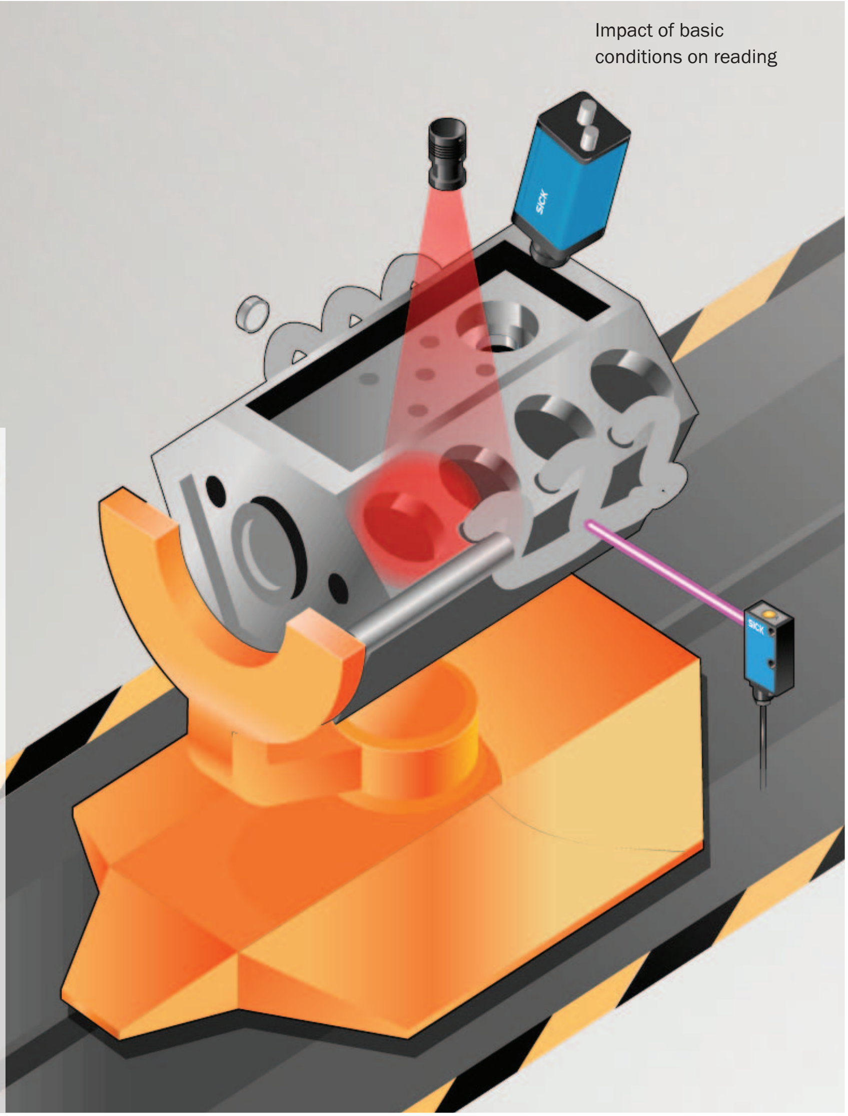




READING

Once the right code has been chosen and the object has been well marked, a suitable system for reading the code can be selected. It is important to note that various factors impact on the quality of the image to be read and, as a result, on the readability of the code. The opposite graphic illustrates the parameters that must be considered each time a code is identified.





Impact of basic conditions on reading

Coding:
– Quality characteristics of data matrix code creation

Marking:
– Overview of marking methods
– Quality characteristics of laser marking
– Quality characteristics of ink jet marking
– Quality characteristics of dot peen marking
– Quality characteristics of electrolytic chemical etching
– Positioning the code mark

Reading:
– Choosing the right reader
– Choosing the right lighting
– Environmental conditions
– Verifying data matrix codes
– Factors for successful reading

Partners – marking systems
Bluhm Systems, BRADY, cab Produktionstechnik, Domino, FOBA Technology + Services, Imaje, Joachim Richter Systeme und Maschinen, KBA-Metronic, Östling Markingsystems, Panasonic Electric Works Europe, ROFIN Laser Marking, Trumpf Laser

READING

1. Readers

Different scanning technologies are used today to identify or read barcodes:

1.1. Laser Technology

Barcode readers operating on the basis of long established laser technology scan the barcode to be identified for light and dark bars. The reflected light is received by the laser scanner, whereby the light from the black bars is weaker than that from the white spaces. The signal received is digitized and then decoded.

Generally speaking, the major benefits of laser scanners include their large reading distances, simple commissioning, depth of field, and price/performance ratio. One drawback is that these barcode readers are not suitable for identifying 2D codes.

1.2. Camera Technology

Readers operating on the basis of camera technology record an image of the object and search through this with image processing algorithms for 1D or 2D codes, which are then decoded. One advantage of camera systems is that all codes can be identified with one device and omni-directionally (360°). Furthermore, image processing is the first technology to allow 2D codes and OCR/OCV texts to be identified, as well as the use of direct part marking.

Based on the different scanning technologies, barcode readers can be used in the following applications:

	Laser Technology	Camera Technology		
Readable Code Structures	1D	1D	2D	OCR/OCV
Applicable Marking Method	Labels Ink jet Laser on synthetics*	Labels Ink jet Laser	Labels Ink jet Laser Dot peening Electrolytic chemical etching	Labels Ink jet Laser Dot peening Electrolytic chemical etching

* Due to the code structure and marking method, the best possible contrast and print quality is required

READING

1.3. Mobile Hand-held Scanners

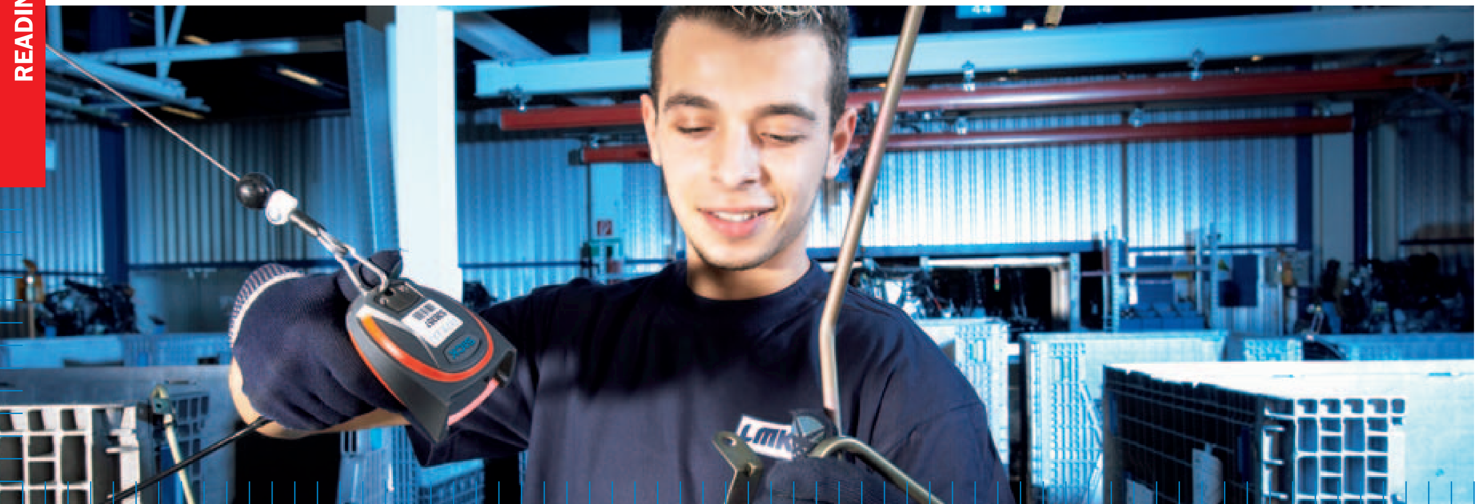
Mobile hand-held scanners based on laser or camera technology can be used for manual code identification. Generally speaking, manual scanning is used for objects that are difficult to access or in areas in which the user requires maximum freedom of movement to identify codes.

Mobile hand-held scanners for 1D, 2D, and OCR identification are available in both wired and wireless form (the latter with a range of 10 to 100 m). USB or RS-232 interfaces as well as keyboard wedges can be used to connect to host computers or POS systems.

Nowadays, all standard marking methods, that is, labels and direct part marking can be supported.

Typical areas of application:

- Office automation/document processing
- Factory automation
- Warehouse and logistics automation



- Transportation logistics
- Point of sales/retail
- Clinical analysis automation

1.4. Fix-mounted Scanners

Fixed-mount scanners based on laser or camera technology can be used on automated conveyor systems or sections. They allow for a high degree of automation because they can be activated and deactivated fully automatically with sensors or from the host computer. It is important that the code is positioned exactly in the reading field of the barcode readers. If the code is positioned incorrectly or the reading field of the selected reader is too small, the code cannot be identified.

Today, fix-mounted scanners offer almost all available industrial interfaces, such as RS-232, Ethernet, CAN, PROFIBUS, PROFINET, DeviceNet, etc. for data connection in factory and logistics automation.

Typical areas of application:

- Identifying circuit boards in the electronics industry
- Variant control in automotive engineering
- Tracing components in the automotive and electronics industries
- Mail sorting
- Document processing
- Packaging identification for foodstuffs, drugs, and cosmetics
- Storage and conveyor systems in logistics automation

READING

When fix-mounted scanners are used for barcode identification, it is also important to consider whether or not the object to be identified is moved:

	Laser Technology		Camera Technology	
	Oscillating Mirror	**Rotating Mirror Wheel**	**Line Scan Camera**	**Matrix Camera**
1D Code Reading	Stationary and little movement	Stationary and in motion	Stationary and in motion	Stationary and in motion
2D Code Reading			Movement	Stationary and in motion
Reading Field Width	Large	Very large	Medium	Small
Possible Object Speed	< 0.10 m/s	< 5 m/s	< 10 m/s	< 6 m/s

The cameras used to read 2D codes are subdivided into two technologies whose functional principles are described in more detail here.

READING

1.5. Functional Principle of the Line Scan Camera

Two laser diodes illuminate a narrow section of a moving object. This illuminated section is captured by the line scan camera. The images that are captured line by line are reassembled as a whole, two-dimensional image by software algorithms in the reader. This image is then scanned for code structures after which the codes are decoded.

The camera sensors used read each line with a frequency of up to 45 kHz and can, therefore, identify the codes at very high speeds.

1.6. Functional Principle of the Matrix Camera

The image field of a matrix camera is normally illuminated two-dimensionally by means of LED lighting. This illuminated image detail is captured two-dimensionally, making it comparable to the classic digital camera. The image captured in this way is, in turn, saved to the image memory, scanned for code structures, and decoded. Following this, the next image is captured. Between 10 and 200 images are captured every second, depending on the dynamic response of the camera chip and the size of the image detail.

READING

1.7. Evaluation of Fix-mounted Barcode Readers (Camera Technology)

Bearing in mind the available scanning technologies and reader types, as well as the wide range of identification tasks involving different marking methods, all of the readers possess many advantages and disadvantages when examined in detail. These should be considered individually in line with the intended application.

The following evaluations, therefore, relate only to fix-mounted barcode readers based on camera technology for identifying 1D and 2D codes:

Advantages of Fix-mounted Line Scan Cameras

Advantages	Customer Benefits
Large reading field width	Straightforward positioning of codes and reader
Image length defined by reading interval/trigger	High level of process reliability for code identification
High transport speeds < 10 m/s	Fast processes

Disadvantages of Fix-mounted Line Scan Cameras

Disadvantages	Example Impact
2D codes cannot be read standstill	Data loss if machines are defective
Captured image is distorted if vibrations occur	Increased design-related outlay (damping)
No focus adjustment means low depth of field	Increased design-related outlay (object guidance)

Advantages of Fix-mounted Matrix Cameras

Advantages	Customer Benefits
Digital camera principle "freezes" moving images	2D codes can be read both when stationary and in motion, no data loss if machines are defective, lower integration outlay in the case of vibration
High depth of field	Lower design-related outlay (object guidance)
Multiple reading	Increased reading reliability

Disadvantages of Fix-mounted Matrix Cameras

Disadvantages	Example Impact
Small reading field in width and height	More difficult to position codes and reader
Only medium transport speeds < 6 m/s	Limited transport speed

1.8. Choosing the Right Reader

To what degree should the application be automated? Are fix-mounted scanners or mobile hand-held scanners better suited to the application?

1D or 2D application, which reading system is best suited?

Are labels or directly marked codes being used?

Does the code have to be read omni-directionally?

How large is the required reading field?

To what extent can the distance between the reader and object vary, in other words what depth of field (DOF) is required?

At what speed does the object or code move?

Fix-mounted scanners are generally used to achieve a high degree of automation, since they can be controlled directly by a PLC or PC. Conveyor sections are almost always fully automated and consequently equipped with fix-mounted devices. Mobile hand-held scanners are most commonly used at work centers where work is carried out by hand, and in the case of objects whose shape and size, and consequently the code position, vary significantly.

If the application is exclusively 1D, laser scanners are normally the best solution because they cover a larger reading field and provide significantly greater depth of field. In 2D applications, camera systems with line scan or matrix camera sensors are used, since they are able to read two-dimensional codes.

Directly marked codes place significantly higher demands on the reading system. A camera system is normally necessary to identify these codes. Codes applied to labels are usually very high in contrast and of high quality, often resulting in lower demands on the code reader.

Camera systems are particularly well suited to omni-directional reading of 1D and 2D codes, since an image of the code is stored in the image memory and decoded. Reading therefore takes place independently of the angle at which the object is positioned.

The more the position of the code varies, the greater the reading field of the reader has to be. The reading field size can be found in the technical data for each product. Furthermore, the minimum dot size (2D)/resolution (1D), as well as the absolute geometric code size must be taken into account so that the code fits into the reading field and can still be read at the required distance.

The reader must be selected depending on the extent to which the distance between the reader and object varies. In contrast to camera systems, laser scanners have a very high depth of field, that is, the distance to the reader can fluctuate considerably and the code can still be identified reliably.

If the code is to be read whilst stationary or in mixed mode (stationary and in motion), this application requires a matrix camera. If, on the other hand, the object moves at speed, the line scan camera would be the better choice.

2. Illuminating the Object

In addition to the right reading system, appropriate illumination is fundamental to stable code reading. The choice of illumination is motivated by two aims:

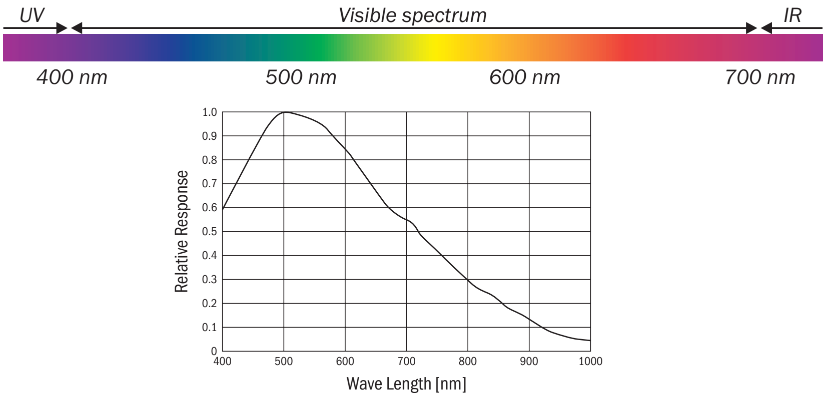
- The contrast between code and background should be increased
- Irrelevant elements and structures should be suppressed

Characteristic features of illumination:

- The wave length of the light, that is, the color of illumination
- The intensity of the light
- The polarization of the light

Wave Length

The reflectance behavior of the object surface and the spectral sensitivity of the camera chip determine the appropriate color. Red or white lighting is often used for code reading. The advantage of white light is that it is reflected by all object colors because it is comprises the entire visible color spectrum.



Example of the spectral sensitivity of a camera chip: can be used throughout the entire visible range.

Intensity

The intensity of the light depends on the reflectance behavior of the surface. With low-reflecting materials, or if the ambient light is very intense or varies greatly, the intensity of the illumination must be suitably high. At high transport speeds, matrix cameras require flashlight to “freeze” the moving image.

Polarization

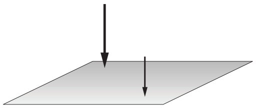
Polarization filters are used in barcode readers to suppress or minimize reflections on images captured through glass because reflecting light is (partly) polarized.

READING

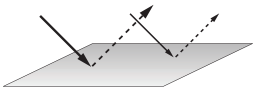
Polarization filters can also improve contrast because they can be used to suppress scattered light – which is also (partly) polarized – from shiny surfaces.

2.1. Behavior of an Object when Illuminated

Depending on the properties of the material that the object surface is made from, light that hits it is either absorbed, reflected, transmitted, or emitted. The lighting must be adjusted to achieve sufficient contrast between code and background.



Absorption

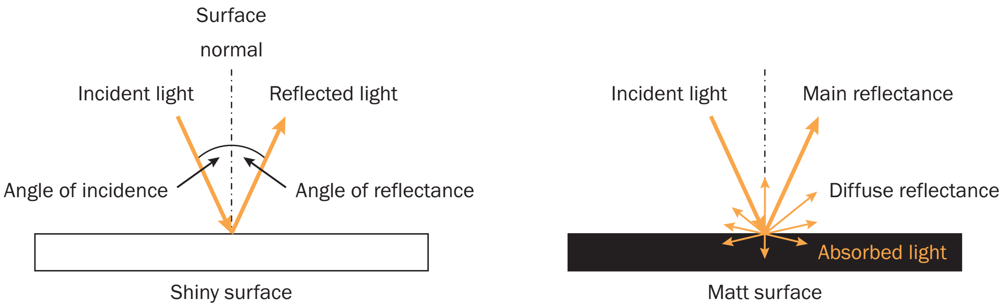


Reflectance

In most applications, the reflectance and absorption behavior of the object surface is used in the code reading process. The code and its background reflect the light that hits the object surface to varying degrees in the direction of the reader; this produces the contrast.

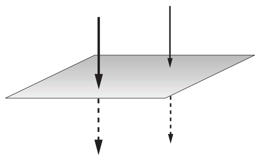
Shiny surfaces reflect light back according to the angle of incidence. Matt surfaces, on the other hand, absorb part of the light, scatter part of the light diffusely, and reflect the remainder.

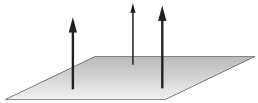
Example of reflectance behavior of shiny and matt surfaces.



Transmittance is used in the case of translucent objects. The object is positioned between the light and the reader for this purpose. The different transmittance behavior of the code dots generates the required contrast.

Emittance is used to read fluorescent codes. An invisible code is stimulated with UV light and becomes visible to the camera and – depending on the spectral range emitted – the human eye.


Transmittance

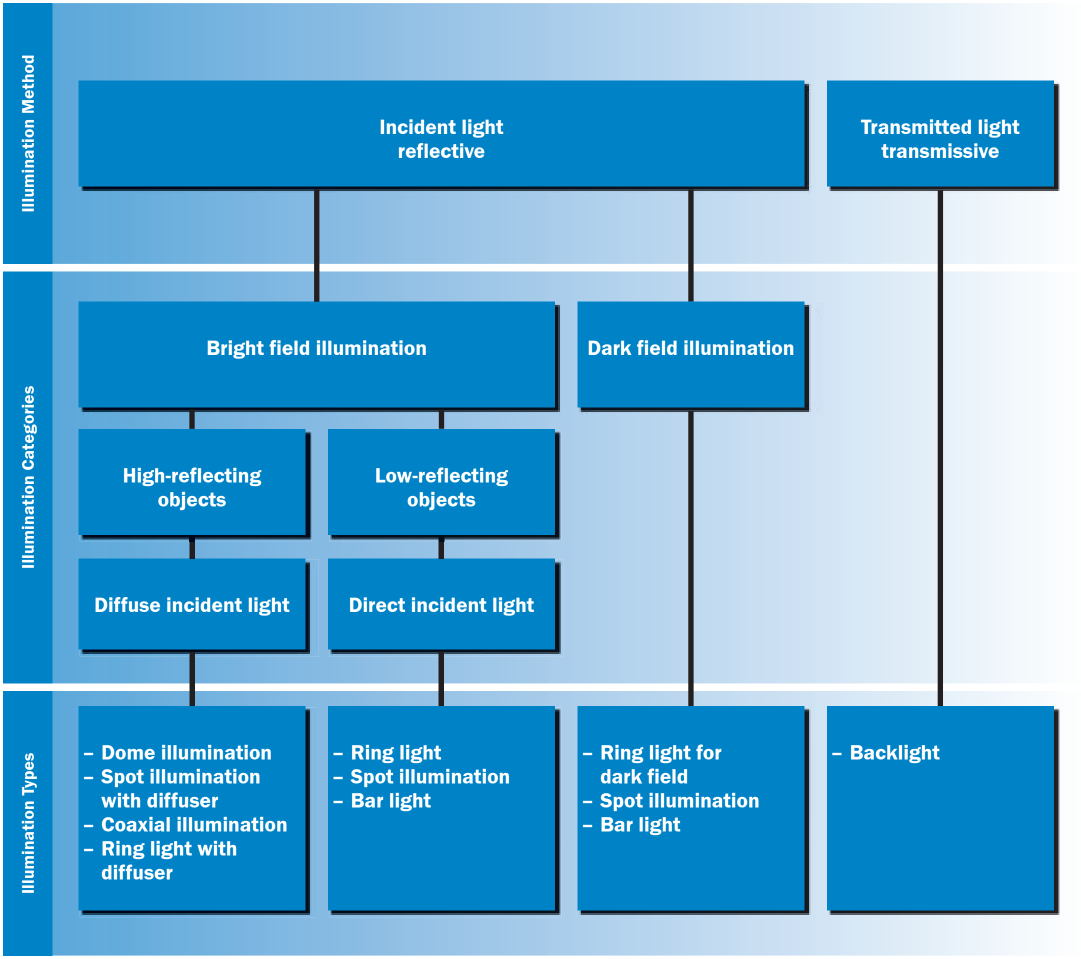

Emittance

2.2. Illumination

Choosing the correct illumination is central to achieving a good reading result. If the reader is equipped with internal lighting, different types of illumination can be achieved by positioning the reader in different ways. By comparison, however, external lighting can be adjusted to suit the required application much more flexibly.

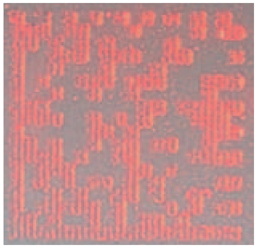
READING

Illumination variants



2.2.1. Illumination Methods: Incident Light or Transmitted Light?

Incident light is used in most code reading applications. Transmitted light, on the other hand, is only used for transparent objects, for instance glass panes, glass bottles, etc. The contrast between the code and transparent objects is produced by illuminating the code.



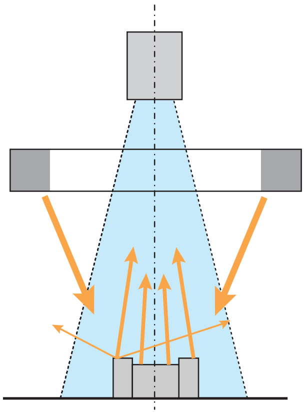
Example of illumination with transmitted light

2.2.2. Illumination Categories: Bright Field or Dark Field Illumination?

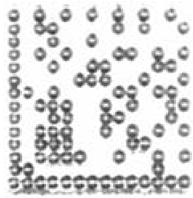
Depending on the code marking, either bright field or dark field illumination should be used. These two illumination categories differ according to the position of the lighting in relation to the optical axis of the camera system.

Bright Field Illumination

The light source is aligned in relation to the camera and object in such a way that the majority of the reflections are parallel to the optical axis of the camera, and therefore hit the image sensor of the camera directly. All objects that are more or less at a right angle to the optical axis are visible to the camera. All other objects appear dark. Bright field illumination is suitable for the majority of marking methods, and is, for this reason, the most commonly used for code reading.



Schematic illustration of bright field illumination



Example of bright field illumination

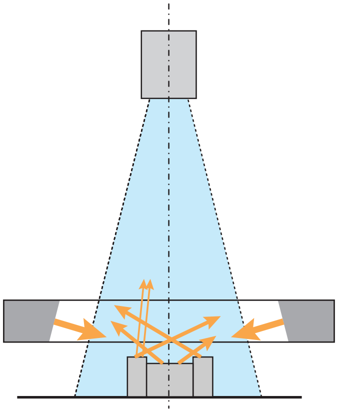
READING

READING

Bright field illumination as direct or diffuse incident light?

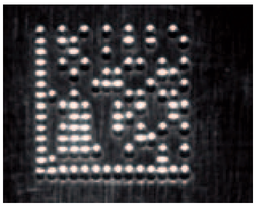
- Direct incident light:
  Light that predominantly hits the object parallel to the optical axis is referred to as direct incident light. This is used mainly for low-reflecting surfaces because high illumination intensity and good contrast can be achieved with little energy.
- Diffuse incident light:
  Light that is scattered in all directions homogeneously and illuminates the object evenly and "softly" is referred to as diffuse incident light. This type of illumination is used for very shiny, highly reflective surfaces to reduce interfering reflections.
  The distance between object and light must be very small to achieve homogeneous illumination. In some applications, this is not possible due to the prevailing parameters and constraints.

Dark Field Illumination



Schematic illustration of dark field illumination

The light source is aligned in relation to the camera in such a way that the majority of the reflected light is not parallel to the optical axis of the camera. Only light that reflects on the edges runs parallel and thereby falls on the image sensor of the camera. As a result, the edges of the object are illuminated while the background remains dark. The dark field illumination method is particularly well suited to dot peening.



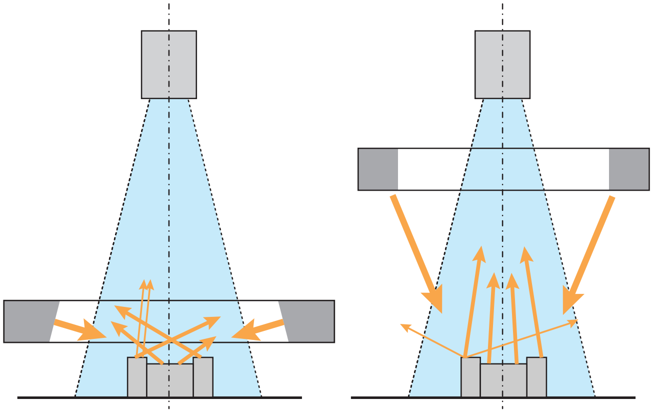
Example of dark field illumination

2.2.3. Illumination Types

The following are suitable for use with the different illumination methods (incident light or transmitted light), and – by changing the position – can also often be used for multiple illumination categories (bright field or dark field).

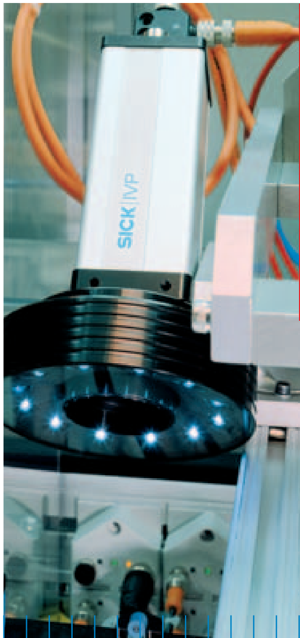
Ring Light

Ring lights are often used for code reading. Depending on the diameter of the ring, the distance to the object, and the angle of the LEDs' reflected beam, the ring light is suitable for both bright field and dark field illumination. The reading field can also be illuminated homogeneously by means of a diffuser attachment, that is, a direct incident light becomes a diffuse incident light.



Ring lights as dark field and bright field illumination

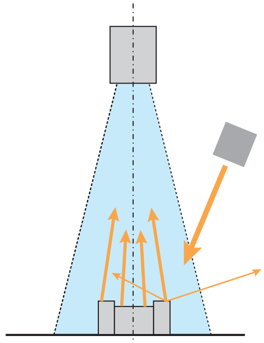
Ring light in application



READING

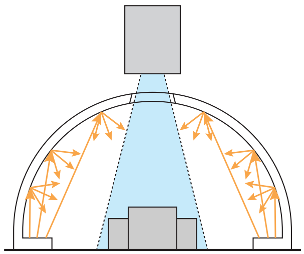
Spot Illumination

Spot lights generate direct or, if a diffuser attachment is used, diffuse incident light. They are used when an object has to be illuminated over large distances. Depending on the position and angle in relation to the optical axis of the camera, the spot light can be used for both bright field and dark field illumination.



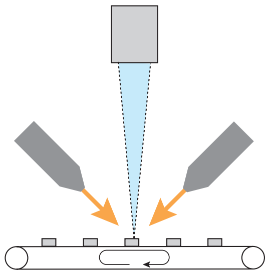
Dome Illumination

Dome illumination generates diffuse light and is used on shiny surfaces to suppress unwanted reflections. The object to be identified must be positioned within the dome light. This can be a disadvantage in the case of automated processes and varying object shapes and sizes.



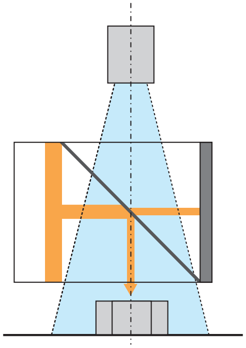
Bar Lights

Bar lights (also known as line lights) are used to provide direct illumination. A wide variety of bar lights are available to suit the requirements of different applications.



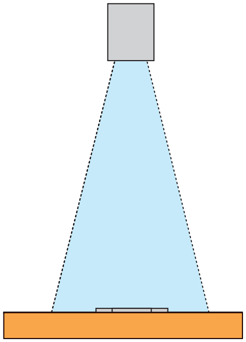
Coaxial Illumination

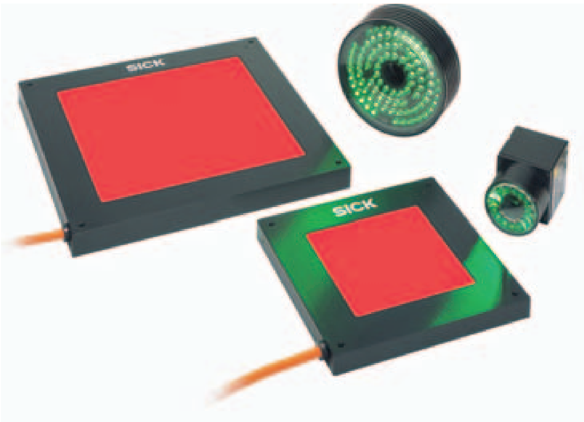
Coaxial lights produce a very homogeneous, diffuse light that illuminates the entire surface. The coaxial light is positioned below the camera lens or above the object to be identified. The camera sees through the semi-reflective mirror parallel to the light along the optical axis onto the homogeneously and diffusely illuminated object. As a result, the camera is able to capture the object in great detail.



Backlighting

Backlights illuminate a large surface homogeneously and provide transmitted light illumination for contour recognition and code reading (in special applications only). Depending on the application, backlights are also used to produce a diffuse incident light that covers large surface areas.





READING

READING

2.3. Choosing the Right Illumination

The following key questions are important when choosing the right lighting.

How large is the reading field of the camera and the surface to be illuminated?

Are there any application-specific requirements regarding the distance between the camera or lighting and the object?

To what extent must the effects of extraneous light be taken into account?

Which LED color should I choose?

Is the object surface curved/bent?

Is the surface scored?

How much can I spend on illumination?

The lighting should be dimensioned in line with the basic parameters and constraints. Ring, dome, spot, and coaxial lights are available with different diameters providing different fields of illumination. Line lights and backlights can also be used for differing lengths and surface areas. The illuminated surface area is stated on the data sheet of each light.

Diffuse lights and dark field lights often require very short distances. Dome lights, for example, often reach the limits of their application as a result of this.

The lighting should compensate for variations in the intensity of extraneous light and render the application largely independent of extraneous light. The data sheet for the light provides information on the intensity in relation to the surface area. Shading from sunlight, overhead lights, or spot lights may also be necessary.

If the reader does not use a filter to suppress certain wave lengths, any LED color can be chosen. Red lighting is often used for code reading because it is not sensitive to extraneous light. One drawback is that red codes, or black codes on a green background, for example, cannot be recognized because the light is not reflected and the contrast is too low. White lighting has the benefit of recognizing all colors, since white light comprises the entire color spectrum. Green light provides good results in the case of extremely shiny objects.

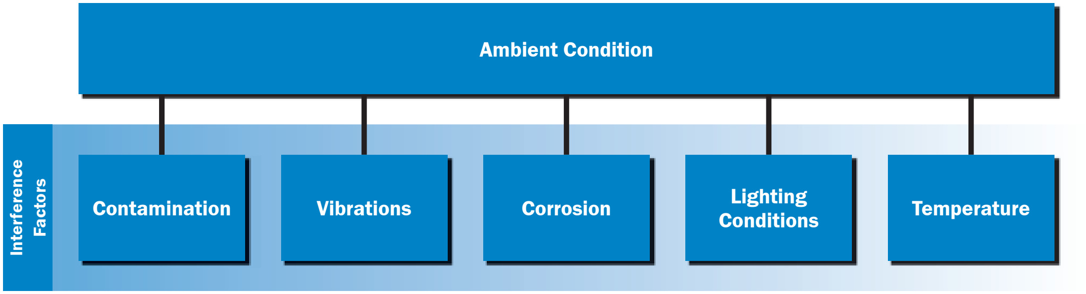
By using homogeneous illumination and perhaps fitting several lights, the position of the code should be fully and homogeneously illuminated.

The incident light should hit the object along the scores, that is, as parallel as possible to them in order to suppress interference structures.

A very high-quality light can cost as much as the reading system itself. For most code identification tasks, however, a simple type of illumination is sufficient.

2.4. Ambient Conditions

Ambient conditions can make the code more difficult to read and should be optimized. In the following, interference factors, their impact, and counter measures are discussed.



- Contamination by oil or dust

  In some applications, it is impossible to avoid the code or reader being contaminated by dust or cuttings. Suction cleaning systems can provide a remedy for this.

  A layer of oil on the object causes reflections that cannot be precisely defined because the thickness and reflectance behavior vary. Lighting positioned in such a way as to prevent the reflections from the film of oil reaching the camera can help here.

- Vibrations
  The extent to which vibrations impact on reading depends on the reading system. Mechanical measures, such as damping systems, can be used.
  Line scan cameras are sensitive to vibrations, since the image is assembled from individual lines. Vibrations can cause the individual lines in the image to become displaced and render the image information unusable.
  Matrix cameras are less sensitive to vibrations because the entire image is "frozen" in a split second.
- Corrosion/oxidation
  Corrosion on metal surfaces (in particular steel and copper) changes the reflectance behavior and the contrast in the code, which can have a negative impact on the reading results. This problem can be solved by using a transparent protective coating, or by avoiding storing marked objects for long periods before the identification process takes place.
- Lighting conditions (intrinsic and extraneous light)
  Penetrating sunlight, bright ceiling lighting, or vehicle headlamps can impair reading. A quick remedy here is to provide shading from extraneous light. A further counter measure is to use light-intensive illumination or light filters.
- Temperature
  The reading systems and lighting are often restricted to a certain temperature range. If the ambient temperatures are higher or lower than the permitted operating temperatures, there is no guarantee that the camera chip will continue to function properly.

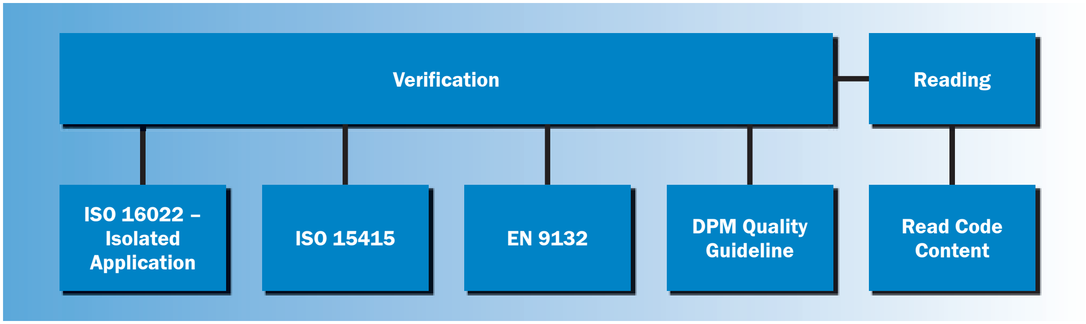
3. Verification of Data Matrix Codes

In many applications, it suffices to read the data content of the code and forward it to the host computer. Some applications, however, also require the quality of the code to be evaluated (this is also know as verification).

Verification indicates whether a code possesses particular quality criteria and where weak spots or errors occur.

An example of this is “read after print”. A code reader verifies the code immediately after it is marked and reports whether the marked code is of a high enough quality. If the marking process deteriorates, it can be adjusted straight away, thus ensuring that codes are identified reliably in the downstream process chain.

The quality criteria for verifying the Data Matrix ECC200 are defined in different standards. The choice of the “appropriate” standard is determined by the purpose of verification.



3.1. Verification in Accordance with ISO/IEC 16022

ISO/IEC 16022 Information technology – International symbology specification – Data Matrix

Purpose: Isolated application – evaluation of code quality and readability in self contained production processes.

Standard ISO/IEC 16022 primarily relates only to data matrix codes printed on labels. The code is read and evaluated with the configured scanner settings. Illumination is not explicitly mentioned. In other words, all possible types of illumination and lighting positions can be applied. Alterations to the camera settings or lighting change the evaluation of the code.

Nevertheless, verification in accordance with this standard can be used as a very practical internal quality control for isolated applications. This does not necessarily involve verifying the actual code quality, but rather the interaction of code, marking system, and reading system within a process chain or production line. This makes it possible to monitor both the way in which the mark is made and the conditions at the reading station during ongoing operations. The aim here is to achieve consistent quality in code production and stable code reading in downstream production steps. For example, a typical "read after print" application is the printing of labels. Grading in accordance with ISO/IEC 16022 is used to identify changes in print quality, for example due to an empty ink cartridge. The grading (result of the evaluation) is output by the barcode reader with grades A to F or numeric values 4 to 0.

3.2. Verification in Accordance with ISO/IEC 15415

ISO/IEC 15415 Information technology – Automatic identification and data capture techniques for barcode print quality – Two-dimensional symbols

Purpose: Generally valid evaluation of code quality and readability independent of production process.

Standard ISO/IEC 15415 primarily relates only to data matrix codes printed on labels. Qualification, however, is carried out with special verification devices called “verifiers”.

The device parameters as well as the light’s intensity and angle of reflected beam have to be set as defined in the standard. The verifiers are calibrated such that code qualification always yields the same result, irrespective of which verification device is used. Consequently, this standard is suitable for verifying 2D codes because it is important to ensure that they can be read by any reading system at any production location. The grading (result of the evaluation) is output with grades A to F or numeric values 4 to 0.

3.3. Verification in Accordance with EN 9132

EN 9132 Aerospace series – Quality management systems – Data matrix quality requirements for parts marking

Purpose: Supplement to ISO/IEC 15415 and ISO/IEC 16022 covering evaluation of the quality and readability of directly marked codes in aviation and aerospace.

EN 9132 also accounts for laser, dot peening, and electrolytic chemical etching marking methods. The following additional criteria are evaluated for this purpose: dot center offset, dot ovality, dot size, and angle of distortion in the code mark. Since this standard also covers the evaluation of directly marked data matrix codes, it is also used in other industries apart from aviation and aerospace.

3.4. Verification in Accordance with AIM DPM-1-2006

Direct Part Marking Quality Guideline

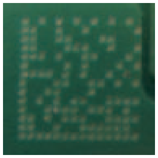
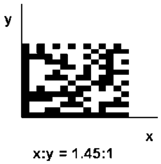
Purpose: Supplement to ISO/IEC 15415 covering evaluation of the quality and readability of directly marked codes.

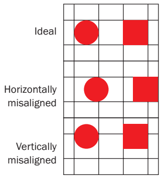
The Direct Part Marking Quality Guideline accounts for the following evaluation criteria: damage to fixed finder patterns, supplement to modulation in ISO/IEC 15415, and determination of final result/grading. This standard can be applied to all directly marked data matrix codes.

READING

3.5. Evaluation Criteria for Verification

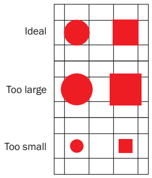
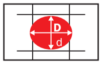
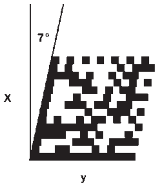
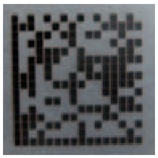
The following evaluation criteria are used for verification depending on the standard:

Evaluation Criterion	Description		Grade		Use in Accordance with Standard			
					ISO/IEC 16022	ISO/IEC 15415	EN 9132	AIM DPM
1. Decoding		Checks whether or not a code is generally readable. An A means easily readable, while an F means unreadable.	A (4.0) F (0.0)	Passes Fails	•	•		•
2. Symbol contrast		Checks the contrast between the bright and dark dots in the code.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	SC ≥ 70 % SC ≥ 55 % SC ≥ 40 % SC ≥ 20 % SC < 20 %	•	•	SC > 20 %	CC ≥ 30 % CC ≥ 25 % CC ≥ 20 % CC ≥ 15 % CC < 15 % (cell contrast)
3. Print growth		Checks the difference between the ideal and actual dot size.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	–0.50 D' ≤ 0.50 –0.70 D' ≤ 0.50 –0.85 D' ≤ 0.50 –1.00 D' ≤ 0.50 D' < –1.00 or D' > 1.00	•			
4. Axial non-uniformity		Checks the ratio between length and width of the code. If the code is stretched or compressed in length or width, it is given a poor rating for its axial non-linearity.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	AN ≤ 0.06 AN ≤ 0.08 AN ≤ 0.10 AN ≤ 0.12 AN > 0.12	•	•		•

Evaluation Criterion	Description		Grade		Use in Accordance with Standard			
					ISO/IEC 16022	ISO/IEC 15415	EN 9132	AIM DPM
5. Unused error correction		Checks how much redundant data had to be used during reading to decode the data content. The best grade is achieved if redundancy was not required at all.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	UEC ≥ 0.62 UEC ≥ 0.50 UEC ≥ 0.37 UEC ≥ 0.25 UEC < 0.25	●	●		●
6. Grid non-uniformity		A grid is placed over the code using the alternating pattern to locate the scan points for decoding. Grid non-linearity checks the extent to which the grid deviates from the ideal grid.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	GN ≤ 0.38 GN ≤ 0.50 GN ≤ 0.63 GN ≤ 0.75 GN > 0.75		●		●
7. Modulation		Checks uniformity of the reflectance of dark and light dots.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	MOD ≥ 0.50 MOD ≥ 0.40 MOD ≥ 0.30 MOD ≥ 0.20 MOD < 0.20		●		● (cell modulation)
8. Fixed pattern damage		Checks the fundamental characteristics of the code (quiet zone, finder and alternating patterns, and reference dots) for defects and calculates an average.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)	AG = 4.0 AG ≥ 3.5 AG ≥ 3.0 AG ≥ 2.5 AG < 2.5		●		●
9. Dot center offset		Checks the extent to which dot centers deviate from the theoretical ideal.		0 % ... 20 %			●	

READING

READING

Evaluation Criterion	Description		Grade		Use in Accordance with Standard			
					ISO/IEC 16022	ISO/IEC 15415	EN 9132	AIM DPM
10. Cell size		Checks the degree of fill of the dot. Particularly in the case of codes created with pin indentations, this often deviates from the nominal size.		60 % ... 105 %			●	
11. Dot ovality		Checks the extent to which dots deviate from a round form.		120°, 90°, 60°			●	
12. Angle of distortion		Checks the deviation of the real angle between the rows and columns of the data matrix code from the ideal. Ideally, this angle is 90°.		± 7°			●	
13. Min. reflectance		Determines the degree to which the object reflects light.						MR ≥ 5 % MR < 5 %
Overall symbol grade		This grading can be considered as a summary of the criteria. The poorest of all the criteria used is always output.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)		Criterion 1. to 5.	Criterion 1., 2., 4. to 8.	Criterion 2., 9. to 12.	Criterion 1., 2., 4. to 8., 13.


SICK
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CAUTION

READING

4. Factors for Successful Reading

Throughout the various chapters it has become clear that a great many factors contribute to good, stable reading. In the following table, four photographs of applications are used to illustrate which errors can occur during the individual steps of the reading process.

CODING	MARKING	
	Marking	Object
 **Interfering reflections**	caused by – inappropriate positioning of the code on the object, for example on a curved surface	caused by – interference structures on the surface – reflective wrapping on packaged products – reflective contaminants, such as oil – curved surfaces that do not reflect light very homogeneously
 **Low contrast**	caused by – inappropriate positioning of the code on the object, for example on an interfering background – selection of an inappropriate marking method or marking parameters for the respective material, for example ink jet with black ink on green circuit boards	caused by – aging of the code, for instance corrosion in metals – interference structures, surface roughness, for example cast parts – similar reflectance behavior of both code mark and code background

READING

READING		
Readers	**Illumination**	**Ambient conditions**
caused by – inappropriate positioning of reader, for example unsuitable angle between reader, light, and object	caused by – selection of unsuitable lighting, for example direct incident light on extremely reflective objects – inappropriately positioned lighting	caused by – reflective contaminants, such as oil – interfering extraneous light, for example sunlight, ceiling lighting, light from floor conveyor vehicles, etc.
caused by – reader and light poorly matched to one another – inappropriate parameter settings for reader	caused by – inappropriate distance between object and lighting – selection of wrong illumination method – lighting insufficiently homogeneous, lighting intensity diminishes towards edges – choice of inappropriate wave length, for example red lighting to read black codes on a green background	caused by – reflective contaminants, such as oil – interfering extraneous light, for example sunlight, ceiling lighting, light from floor conveyor vehicles, etc.

READING

CODING	MARKING	
	Marking	Object
Quality of code geometry	caused by – inappropriate positioning of the code on the object, for example on a curved surface – dots not sufficiently filled, for example inadequate penetration depth of dot-peened codes – distortions in the code due to marking speeds/throughput being too high – dot ovality, for example because the object was moved during ink jet marking – dot center offset, inappropriate marking system configuration	caused by – curved surface – interference structures on the surface
 **Blurred contours**	caused by – selection of inappropriate marking method or marking parameters, for example laser marker not properly in focus	

READING		
Readers	**Illumination**	**Ambient conditions**
caused by – motion blur resulting from poor adjustment of the reader to the transport speed of the object – acceleration of objects during reading – inappropriate parameter settings for reader	caused by – lighting intensity too low or high, for example overexposure of image	caused by – speed of objects in the production process too high – inconsistent acceleration of objects – vibrations at the reading station – dust and aerosols at the reading station
caused by – distance between code and object being beyond the depth of field – motion blur resulting from poor adjustment of the reader to the transport speed of the object	caused by – motion blur resulting from insufficient adjustment of the lighting flash duration	caused by – interfering oil film on the object

PARTNERS

PARTNERS

PARTNERS

As one of the world's leading producers of intelligent sensors and sensor solutions, SICK is a strong and competent partner when it comes to direct part marking. 40 subsidiaries and affiliated companies in over 20 countries across all five continents, and numerous specialist representatives means that customers can benefit from SICK's global presence. In addition to its five production locations in Germany, SICK also produces in Italy, Hungary, Israel, China, and the USA.

In all fields that require end-to-end traceability of components, parts, and products, as well as maximum process reliability and the highest levels of precision, SICK offers innovative, comprehensive solutions for automatic identification. When it comes to processes such as direct part marking, SICK considers the key to system success to be the optimum combination of three areas: "coding", "marking", and "reading". We achieve maximum process quality and process stability because SICK has entered into strong partnerships that perfectly bring together the know-how of leading technology companies. We meet the highest quality standards to ensure the enduring logistical, technological, and economic competitiveness of our customers. Because this is fundamental to providing comprehensive process reliability and investment security.

For this reason, SICK collaborates with competent partners from the field of marking technology to provide specific and intelligent application advice, engineering, and project management as part of our pre-sales services, followed by expert installation, commissioning, site management, and final inspection of the configured systems as part of our after-sales services. Once the system is operational, SICK also offers maintenance, troubleshooting, and replacement parts services, as well as a hotline and an extensive training offering. An all round service to ensure the success of your projects.

If you have any questions regarding contacts, collaboration, further information, or a specific application, do not hesitate to contact us. Further information can be found on our Web site: www.2D-Code.com.

TRUMPF Laser

LASER

The TRUMPF Group is one of the world's leading production engineering companies. TRUMPF innovations set the course in machine tools for sheet metal and material processing, in laser technology, electronics, and medical technology. It plays an active role in defining technical standards and opens up new and more productive possibilities for end users. TRUMPF is the global market and technology leader in the field of industrial lasers and laser systems. Its product range in the field of laser technology encompasses laser cutting and welding machines for 2D and 3D parts, high power CO_2 lasers, diode and lamp-pumped solid-state lasers, as well as marking lasers and systems.

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ROFIN Laser Marking

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ROFIN-SINAR Technologies Incorporated has its operational headquarters in Hamburg, Germany and Plymouth, Michigan. It develops, manufactures, and sells a wide range of laser beam sources and laser-based system solutions for many different applications. With production plants in the USA, Germany, Great Britain, Sweden, Finland, Singapore, and Japan, ROFIN-SINAR is one of the world's leading manufacturers of lasers for industrial material processing, boasting an installed base of over 25,000 lasers at 3,000 customers worldwide.

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Panasonic Electric Works Europe AG distributes the broad range of products and services offered by its parent company Matsushita Electric Works in Japan. SUNX laser marking systems are developed and distributed mainly for factory automation, in particular for the automotive and electronics industries.

With around 15 sales offices in Germany, Austria, Benelux, the Czech Republic, France, Hungary, Ireland, Italy, Poland, Portugal, Sweden, Switzerland, Spain, and Great Britain, and many other cooperation partners – both within and outside of the Panasonic group – Panasonic Electric Works Europe AG provides a comprehensive product and service offering for the whole of Europe.

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Domino

Domino is a world-leader in ink jet, laser, TTO as well as Print & Apply technologies for labels offering total coding and printing solutions. Variable data such as best before codes, bar codes and traceability codes are printed onto products in industries such as food, beverage and pharmaceutical. In commercial printing, system solutions print addresses, barcodes and numbers onto paper products, plastic cards and newspapers. Through a global network of subsidiary offices and distributors, Domino sells to over 120 countries offering extensive customer support.

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Imaje – a 100 % subsidiary of the New York Dover Corporation – develops, manufactures, and sells a wide range of marking technologies such as ink jet and thermal printers, laser coders, and labeling systems worldwide. In addition to its broad selection of software solutions, equipment, and tailor-made services, Imaje offers customized solutions to meet every need. With over 32 offices and 50 dealers, Imaje is represented in over 120 countries worldwide in the food, beverage, pharmaceutical, cosmetic, automotive, and aviation industries, as well as in the fields of synthetics, mechanical engineering, electronics, and cable production.

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Brady is a leading global supplier of innovative labelling, die cut, traceability, safety and security solution. The product portfolio englobes high performance labels, precision die cut materials, printers, software, automatic print and apply systems, data collection systems, service and maintenance contracts and technical support, thus offering a complete and hassle free identification solution for almost any application. Founded in 1914, Brady is headquartered in Milwaukee and employees more than 9,000 people in the United States, Europe, Asia/Pacific, Latin America and Canada.

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Bluhm Systeme

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Bluhm Systems is a full-range provider that designs and develops the entire spectrum of industrial identification solutions, from code/label production to labeling technology. The identification systems are used in almost all sectors, such as the logistics automation, automotive, electronics, and packaging industries. Its product range comprises ink jet and laser coders, as well as thermal transfer and direct thermal printers in the field of coding, RFID-capable label printers and applicators, as well as special labeling machines in the field of labeling.

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KBA-Metronic

KBA-Metronic AG is a midsize technology company that develops and produces identification systems. With its innovative product portfolio, KBA-Metronic offers flexible and practical end-to-end solutions worldwide: ink jet printers, laser, thermal transfer, hot stamping, and personalization scratch-off to name but a few. Sales and service partners in the most important industrial nations ensure customer proximity and customer-focused services in segments including the automotive, electronics, and packaging industries.

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cab Produkttechnik

Since 1975 cab Produkttechnik has been developing and manufacturing equipment and system solutions for product and barcode identification for trade and industry focusing on thermal transfer, laser marking and labeling systems. With its own subsidiaries in USA, France, Russia, Spain, South Africa and Taiwan, cab offers customer-focused support in an international sales and service infrastructure that spans more than 50 countries worldwide.

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When it comes to permanent product marking, identification, and labeling, Östling GmbH in Solingen offers needle marking, scribing, laser, etching, and electrolytic chemical marking methods. Östling has sales offices in Switzerland, Singapore, France, and the USA that serve the machine tool, automotive, aviation, and electronics industries.

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Joachim Richter Systeme und Maschinen

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Joachim Richter specializes in the development and construction of marking and special-purpose machines, as well as laser technology and robot cells for all marking and automation applications. Richter dot peen markers, scribers, engraving machines, stamps, and laser markers are used in small, medium, and large-scale series production, for example in the automotive and aviation industries, which require short marking times. The technology is suitable for variable texts or consecutive numbering.

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Fax: +49 6384 9228-77 · mailto: info@jr-richter.de · www.jr-richter.de

STANDARDS

Organization/Association	Name	Title
International Standards		
International Organization for Standardization/International Electrotechnical Commission	ISO/IEC 15415	Information technology – Automatic identification and data capture techniques – Barcode print quality test specification – Two-dimensional symbols
	ISO/IEC 16022	Information technology – Automatic identification and data capture techniques – Data Matrix bar code symbology specification
	ISO/IEC WD 24720 (WD = Working Draft)	Information technology – Automatic identification and data capture techniques – Guidelines for direct part marking (DPM)
Association for Automatic Identification and Mobility	AIM DPM Quality Guideline	–
Industry-Specific Standards		
Automotive Action Industry Group	AIAG B-4	Parts Identification and Tracking Application Standard
	AIAG B-13	2D Symbology White Paper
	AIAG B-14	Guideline for Use of Two Dimensional Symbols with AIAG Trading Partner Labels
	AIAG B-17	2D Direct Part Marking Guideline
Society of Automotive Engineers (International Aerospace Quality Group)	SAE (IAQG) AS 9132 (for America) AECMA EN 9132 (for Europe) SJAC 9132 (for Asia)	Data Matrix Quality Requirements for Parts Marking
Air Transport Association	ATA SPEC 2000 Chapter 9	Automated Identification and Data
National Aeronautics and Space Administration	NASA-STD-6002	Applying Data Matrix Identification Symbols on Aerospace parts
	NASA-HDBK-6003	Application of Data Matrix Identification symbols to Aerospace parts using Direct Part Marking methods/techniques
Semiconductor Equipment and Materials International	SEMI T2-0298	Specification for Marking of Wafers with a Two-Dimensional Matrix Code Symbol
	SEMI T7-0303	Specification for Back Surface Marking of Double-Side Polished Wafers with a Two-Dimensional Matrix Code Symbol

OUR COMPETENCE IN THE BUSINESS SEGMENTS

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With its intelligent sensors, safety systems, and auto ident applications, SICK realises comprehensive solutions for factory automation.

- Non-contact detecting, counting, classifying, and positioning of any types of object
- Accident protection and personal safety using sensors, as well as safety software and services

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Sensors made by SICK form the basis for automating material flows and the optimisation of sorting and warehousing processes.

- Automated identification with bar code and RFID reading devices for the purpose of sorting and target control in industrial material flow
- Detecting volume, position, and contours of objects and surroundings with laser measurement systems

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Ceská Republika
China
Danmark
Deutschland
España
France
Great Britain
India
Italia
Japan
Nederlands
Norge
Österreich
Polska
Republic of Korea
Republika Slovenija
România
Russia
Schweiz
Singapore
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