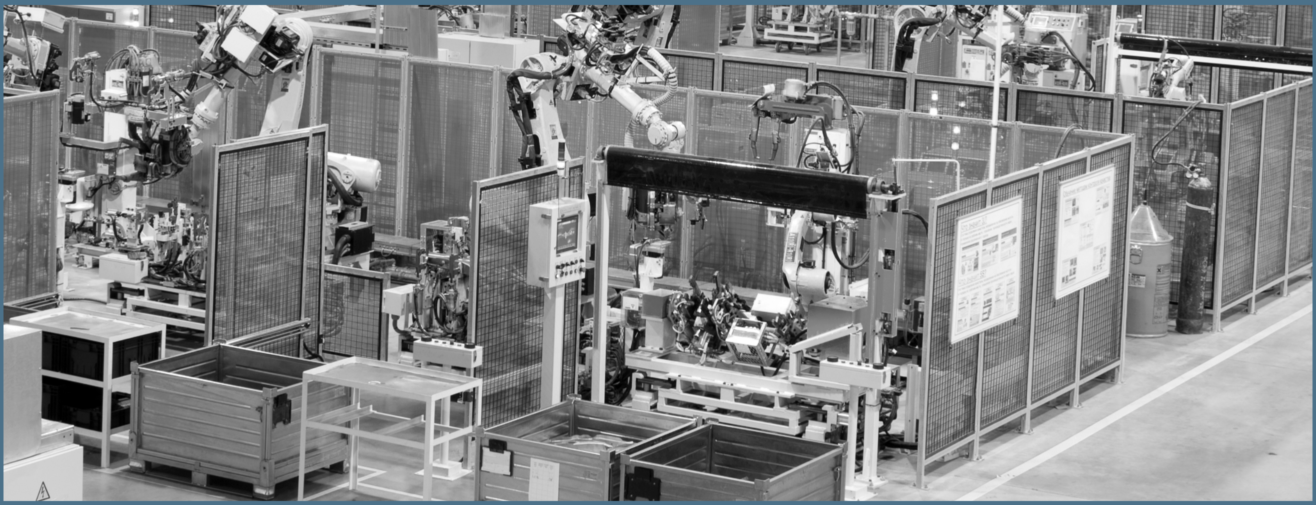
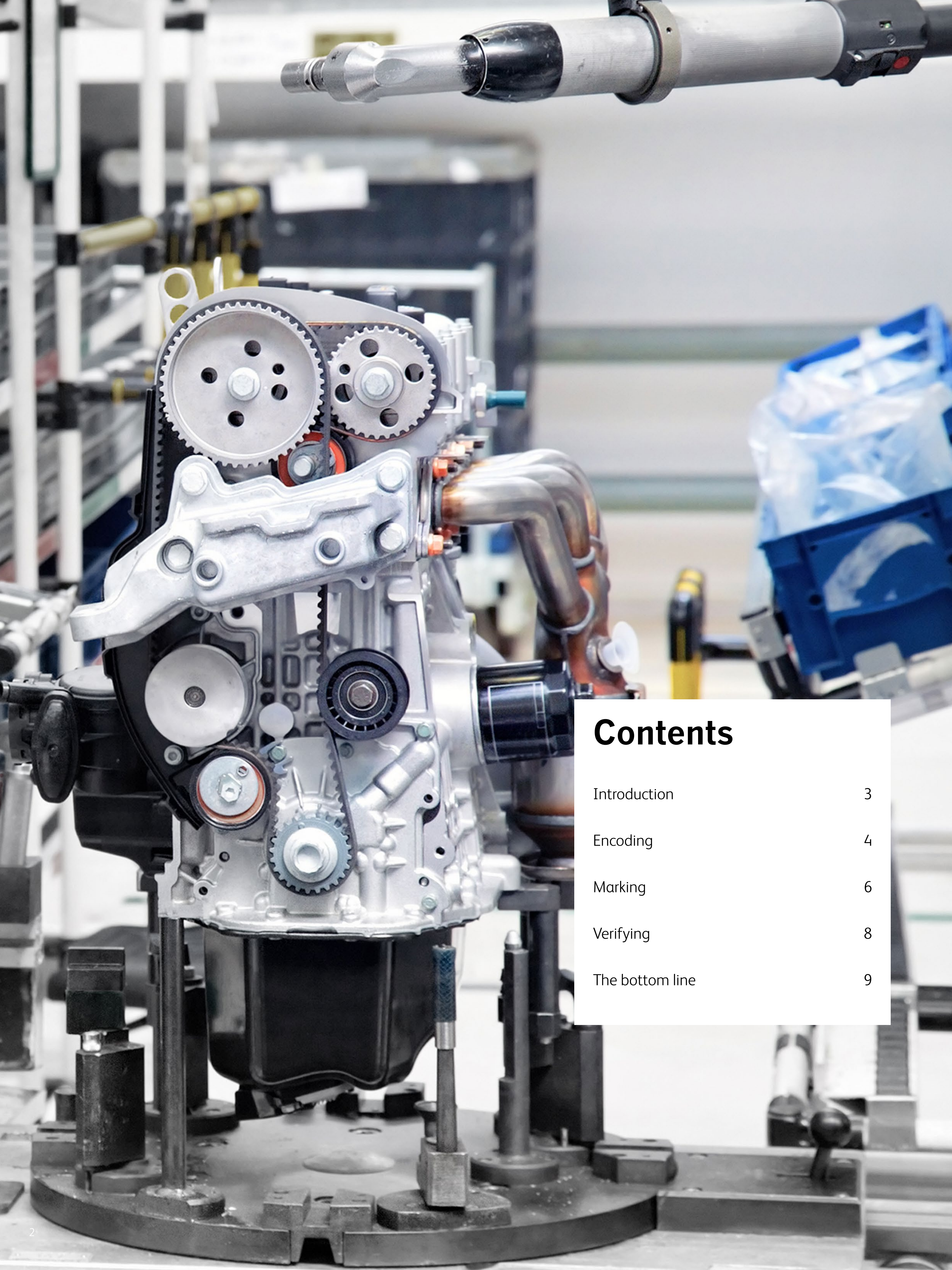
White paper

Implementation of direct part marking identification

Considerations for encoding, marking and verifying automotive and aerospace parts



The practice of Direct Part Mark Identification (DPMI) is used across many industries to identify an array of end use items. This process, also referred to as machine-readable identification, is prevalent in the automotive and aerospace industries for marking alphanumeric and bar codes on individual parts and assemblies. This whitepaper will review the code requirements, options for code application and verification considerations for DPMI.



Contents

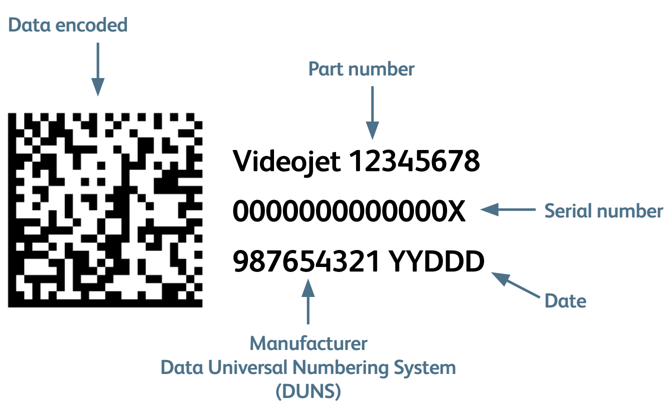
Introduction

DPMI standards have been adopted by a number of associations within the automotive and aerospace industries. Marking parts with machine-readable codes allows for a part to be tracked throughout the manufacturing process and the supply chain. Some manufacturers use DPMI to track high-value parts to deter theft or counterfeiting; to pinpoint parts for service or recalls; to determine liability, and to resolve warranty issues.

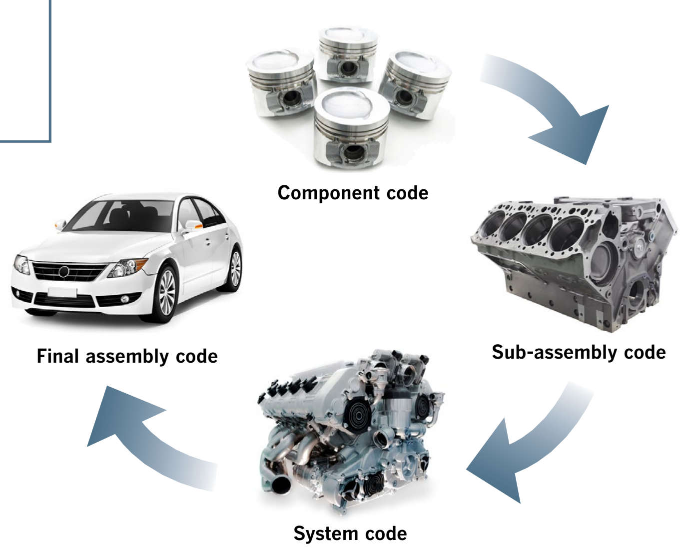
In parts production, the use of machine-readable codes can help reduce the need for manual code entry, increasing code accuracy and speeding-up data exchange. Electronically generated codes that include both 1D and 2D bar codes offer simple data storage and usage for internal IT systems. For over 20 years, the 1D bar code has been widely used for data delivery, but this format is being replaced in many automotive and aerospace production processes with 2D formats. This is because 2D codes are able to contain more information in less space and can be applied with a variety of direct marking methods.

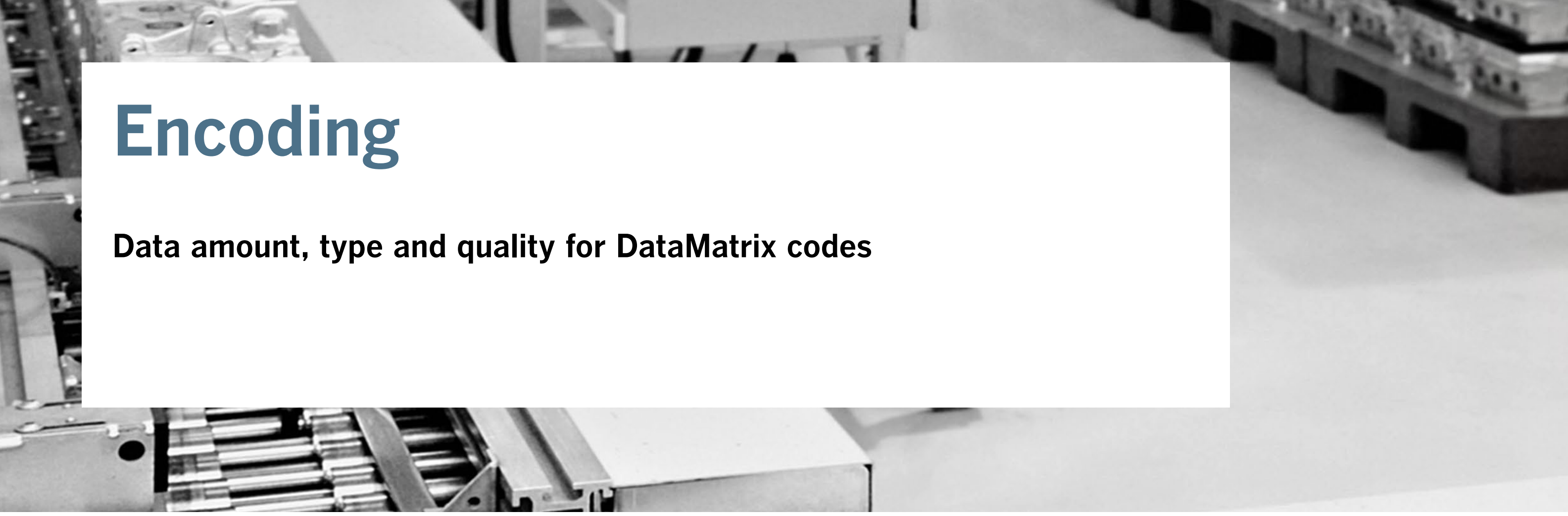
The three main elements in DPMI are encoding, marking and verifying. Encoding is the rendering of a string of data into a pattern of dark and light cells that includes data, padding and error correction bytes to then be used by the marking device. Marking is the imprinting of content directly on your part with the appropriate technology for the substrate. Verification is the act of confirming code accuracy and quality. This is most commonly performed immediately following product imprinting at the marking station.

Example of a DPMI code



Full life cycle traceability





Encoding

Data amount, type and quality for DataMatrix codes

The data type and amount to be encoded determines the DataMatrix size. A DataMatrix code is a 2D matrix bar code consisting of black and white modules arranged in either a square or rectangular pattern. A single symbol can store up to 3,116 numeric or 2,335 alphanumeric characters. DataMatrix ECC 200 is currently the standard in the automotive and aerospace industries.

GS1 – Global Standards One – is the international body that governs standards for bar coding applications. GS1 DataMatrix codes may be printed in a square or rectangular format. The square format is usually used as it has a larger range of sizes and is the only format available for symbols encoding a large amount of data. The largest rectangular symbol can encode 98 digits, while the largest square symbol can encode 3,116 digits.

GS1 DataMatrix symbology has multiple sizes to match various data content. GS1 DataMatrix symbology has 24 sizes of the square format ranging from 10 by 10 modules up to 144 by 144 modules, not including the 1-X surrounding Quiet Zone. The rectangular format has 6 sizes, ranging from 8 by 18 modules up to 16 by 48 modules, not including the 1-X surrounding Quiet Zone.

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

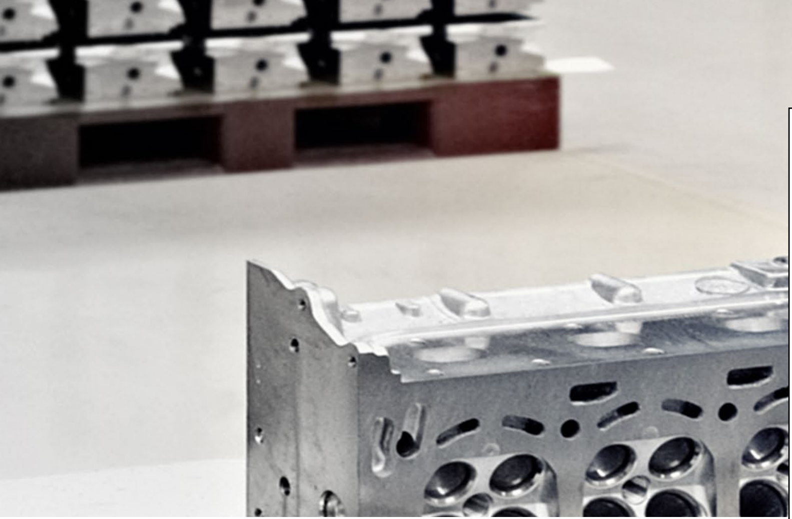
Data capacity of square DataMatrix in relation to symbol size (number of dots in rows and columns) and data type used

Example of a square DataMatrix code

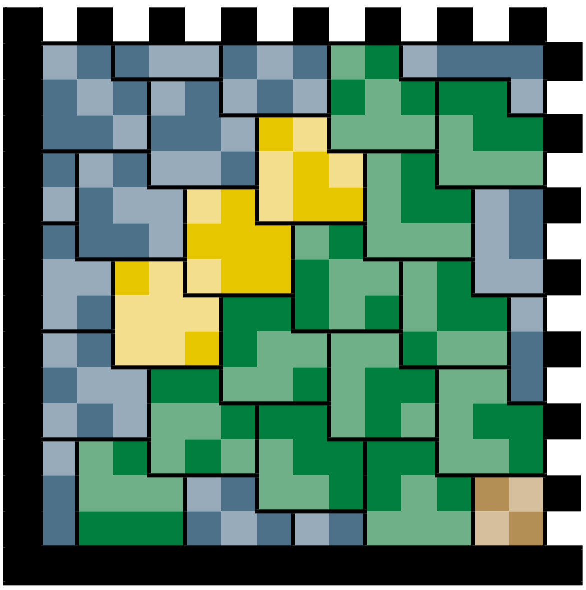
Symbol Size						
Rows	8	8	12	12	16	16
Columns	18	32	26	36	36	48
Data Capacity						
Numeric	10	20	32	44	64	98
Alphanumeric	6	13	22	31	46	72
Byte	3	8	14	20	30	47

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

Example of a rectangular DataMatrix code



Data is stored in a DataMatrix 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 referred to as a "code word," which must contain a minimum of one alphanumeric and two numeric characters.



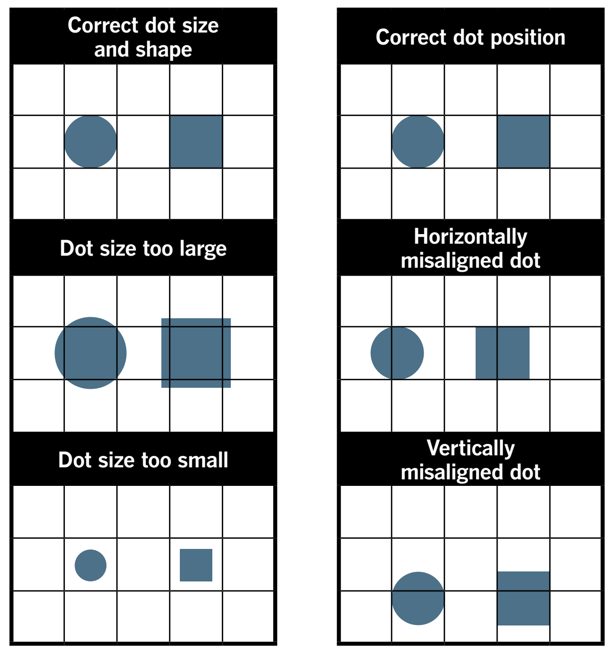
Depiction of how data is distributed in a DataMatrix code. The eight bits of each byte are displayed in the same colour. The solid "L" shape on the outside is the alignment pattern. The other two sides of the finder pattern are alternating light and dark elements. The rest of the code contains bytes of data, padding, error correction, finder and timing, and unused cells.

For ECC 200 codes, user data is encoded with the Reed-Solomon error correction algorithm. With this algorithm, required data content is accompanied by redundant data. If data is destroyed, the redundant data makes it possible to calculate the lost data. Up to 62% of the code can be destroyed or contaminated, depending on symbol size, and calculation is still possible. The additional data placed in the code helps ensure high security, but the required space is still very limited. Data redundancy in DataMatrix codes helps ensure high levels of readability and integrity.

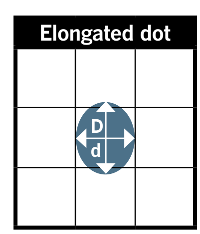
Quality of codes created

For DataMatrix codes to be readable and reliable there are other considerations outside of the basics of code creation. The shape of the dots inside a DataMatrix code can be either round or square. Methods such as dot peening and inkjet produce round dots, and according to standards for the codes, these dots should not be more than 105% larger or less than 60% smaller than the ideal dot size. If the dots are too big, they can touch or overlap each other and become one large dot, making the code unreadable. If the dots are too small, there will be too much white space in between them, providing insufficient printing for a reliable code. There are also threshold values established for deviations from the ideal circle to ensure the round dots produced will deliver a code that can be read reliably.

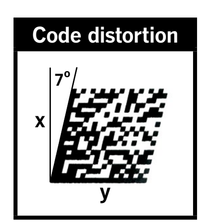
The position of the dots inside the matrix is essential for code reliability. The dots should not deviate from the reference grid, or the ideal dot position (dot centre), either vertically or horizontally. In addition, the code should not be distorted. The ideal angle between the X and Y axis is 90°, but a deviation of 7° is tolerable, according to current code standards.

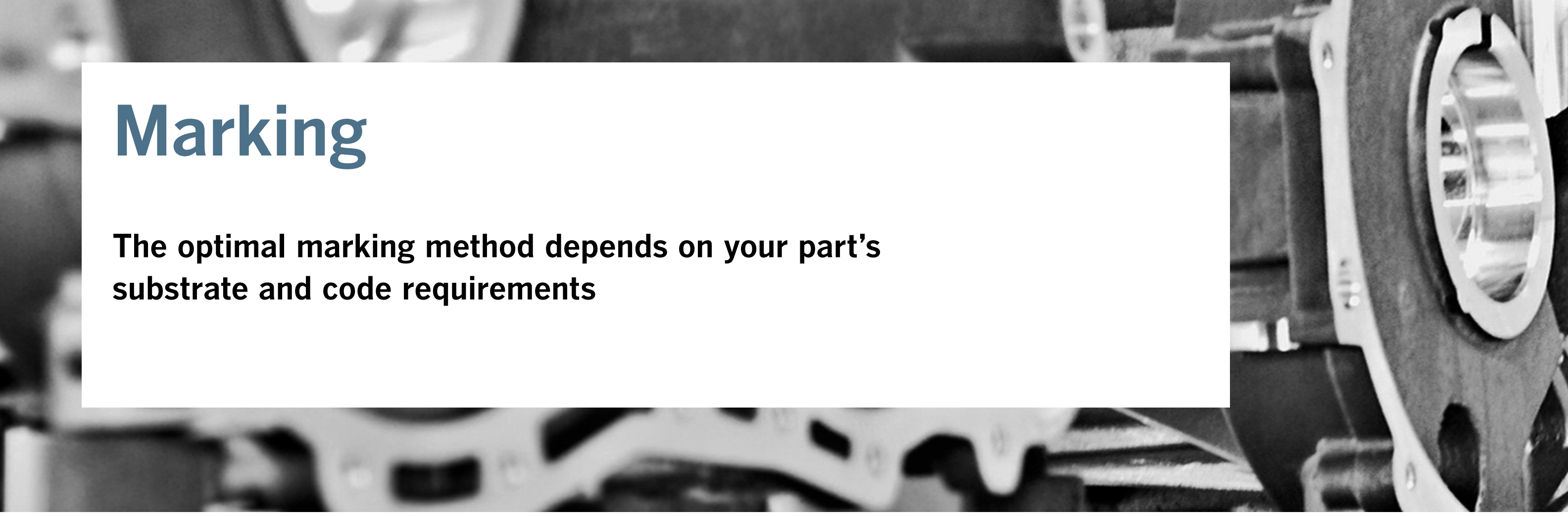


It may only be possible to produce round dots, depending on the marking method chosen. There are parameters set for deviations from the ideal circle shape to ensure the code can be read. The difference between "D" and "d" should not be more than 20% of the dot size.



Distortion of the code can occur during marking or reading, and every effort should be made to avoid it. The ideal angle between the X and Y axes should be 90°. A deviation of 7° is allowable.





Marking

The optimal marking method depends on your part's substrate and code requirements

Aside from selecting code formatting and content, it is also important to consider the best method for marking the part. For the automotive and aerospace industries, the most common methods are laser marking, continuous inkjet printing, dot peening and electrochemical etching.

CO_2 laser coders use infrared laser light generated via radio frequency discharge in a carbon dioxide gas mixture. These laser systems code thermally by changing the surface colour melting, foaming or removing the material surface to create the code.

UV laser uses ultraviolet light to produce 'cold' marking that is safe and has damage-free print capability on many substrates. UV lasers are ideal for direct marking of permanent, high-grade codes to help prevent the risk of counterfeiting or for product traceability.

With Continuous Inkjet (CIJ) technology, a stream of ink enters a nozzle in the printhead, and an ultrasonic signal breaks the stream into tiny drops. These drops separate from the stream and receive a charge that determines their vertical flight to form the characters printed on the product.

In dot peen marking, an indenting pin is used to create an indentation for each dot in the DataMatrix code.

Electrochemical etching removes layers of material via electrolysis. This chemical etching process takes an image on a stencil and transfers it to an electrically conductive product by the action of electrolyte and electricity.

Common marking options comparison

	Laser	Continuous Inkjet	Dot Peening	Electrochemical Etching
Materials that can be marked Variety of substrates	High	High	Average	Low
Flexibility Print on difficult surfaces, distance between part and marking device	High	Average	Average	Low
Investment/initial outlay	High	Average	Low	Low
Ease of integration Ease of communicating with PLC in production cell and space needed for installation and maintenance	High	High	Average	Low
Type of marking method *Non-contact* (part is not touched by marking apparatus) *Contact* (part is touched by marking apparatus)	Non-contact	Non-contact	With contact	With contact
Abrasion resistance of mark	High	Low	High	High
Mobility Ease of moving marking equipment to other locations on the production line	Low	High	High	High
Thermal or chemical stress	Yes	No	No	Yes

Considerations for type of substrate and product code requirements affect the selection of the best marking method. The table below outlines the types of substrates that are best-suited for each of the technology types.

Printing technology and substrate suitability

		Aluminium	Copper	Titanium	Iron	Steel	Magnesium	Ceramic	Glass	Synthetics
Laser	CO_2 laser								•	•
	Solid state laser	•	•	•	•	•	•	•		•
	UV laser	•	•	•	•	•	•	•	•	•
Continuous inkjet		•	•	•	•	•	•	•	•	•
Dot peening		•	•		•	•				•
Electrochemical etching		•	•	•	•	•	•			

DataMatrix code printed with CIJ technology

DataMatrix code printed with laser technology

DataMatrix code printed with dot peen technology

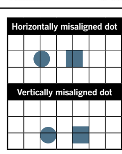
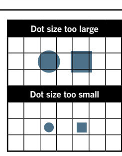
Talk to your coding partner expert for help selecting the right solution for your marking application.

Verifying

Confirmation of 2D code quality and content accuracy

Verification of 2D codes helps producers gauge the performance of the DPMI equipment in use. Verification systems can instantly provide alerts if the codes produced do not pass verification, so any issues with the equipment can be addressed and corrected. Verification systems typically include a fixed camera, optics, lighting, part fixtures and some kind of verification software. DPMI verification systems should be tailored to the application, providing specific feedback required by individual users. When selecting a verification system, users need to know what the equipment is checking and exactly how the verification data is being used to help comply with code specification.

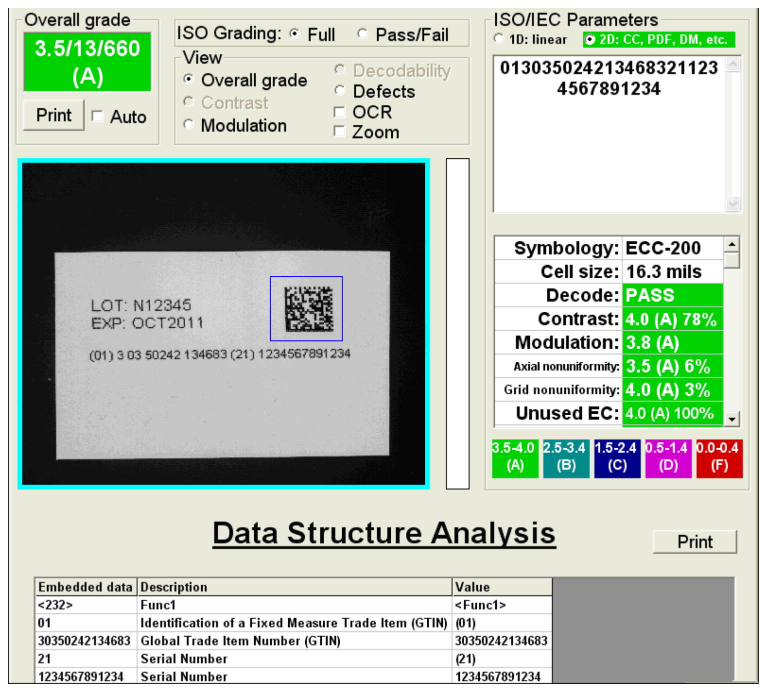
Depending on the standard, the following criteria are used to evaluate DataMatrix codes:

Evaluation criteria	Description		Grade		Use in accordance with Standard		
					ISO/IEC 16022	EN 9132	AIM DPM
Decoding		Checks whether or not a code is generally readable. An 'A' means easily readable, an 'F' means unreadable.	A. (4.0) F (0.0)	Passes Fails	•		•
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)
Axial non-uniformity		Checks the ratio between length and width of a code. If the code is stretched or compressed, it is given a poor rating for 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	•		•
Unused error correction		Checks how much redundant data had to be used during reading to decode the data content.	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	•		•
Dot centre offset		Checks the extent to which dot centres deviate from the theoretical centre.		0% ... 20%		•	
Cell size		Checks the degree of dot fill.		60% ... 105%		•	
Overall symbol grade		Summarizes the criteria. The poorest out of all the criteria used is always output.	A (4.0) B (3.0) C (2.0) D (1.0) F (0.0)				

Each specific application will define not only code parameters, but also print quality and specifications for data formats, identifiers, and transfer structures. The same is true with a DPMI verification system.

When selecting a DPMI verification system, it should not only be able to provide feedback on its set-up, but it should also be able to log, report, and share results as well as images and verification data. Additionally, the system should track, record and score quality metrics for each part verified, providing time and date stamps as well as bitmap images. Metrics should be based on international standards such as ANSI and GS1.

Optimised DPMI solutions will feature an operator-friendly interface that allows users to enter set-up information. Common set-up information includes user name, lighting parameters, as well as camera-specific details such as exposure values and optical settings.



Example of a vision system verifying a DataMatrix code quality and data accuracy

The bottom line:

Direct part marking is essential to full cycle traceability throughout the manufacturing process and supply chain.

From basic 1D to 2D to DataMatrix codes, the success of your product marking and verification is dependent on the DPMI system that you select.

At Videojet, we understand the complexity of direct part marking as well as the nuances of lean manufacturing. Capitalizing on our expertise, many automotive and aerospace OEM's and part suppliers already trust Videojet. They utilise our global team of experienced service engineers and coding specialists to help design and integrate coding solutions based on their unique application needs. Combined with a wide range of marking technologies for nearly every application, we can help you specify the ideal coding solution for your production environment and help drive superior uptime in your operation.

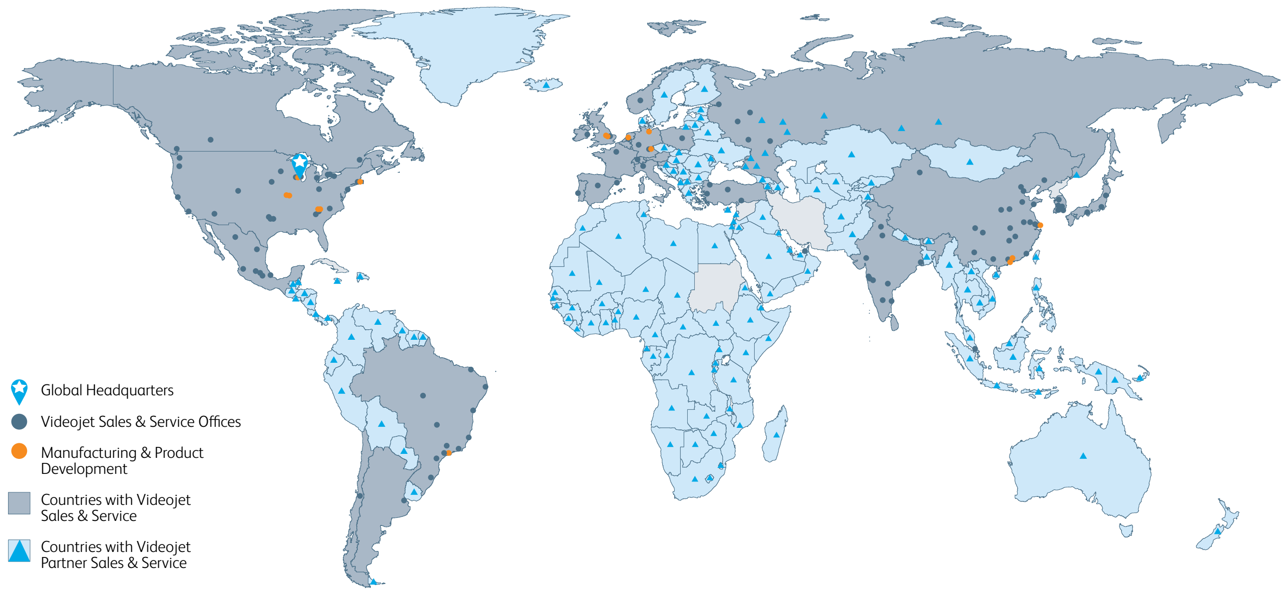
Trust the expertise of a global leader in product coding. Trust Videojet.

Peace of mind comes as standard

Videojet Technologies is a world-leader in the product identification market, providing in-line printing, coding, and marking products, application specific fluids, and product life cycle services.

Our goal is to partner with our customers in the consumer packaged goods, pharmaceutical, and industrial goods industries to improve their productivity, to protect and grow their brands, and to stay ahead of industry trends and regulations. With our customer application experts and technology leadership in Continuous Inkjet (CIJ), Thermal Inkjet (TIJ), Laser Marking, Thermal Transfer Overprinting (TTO), case coding and labelling, and wide array printing, Videojet has more than 345,000 printers installed worldwide.

Our customers rely on Videojet products to print on over ten billion products daily. Customer sales, application, service and training support is provided by direct operations with over 4,000 team members in 26 countries worldwide.
In addition, Videojet's distribution network includes more than 400 distributors and OEMs, serving 135 countries.



Call us free on **0800 500 3023**
Email **uksales@videojet.com**
or visit **www.videojet.co.uk**

Videojet Technologies Ltd.
4 & 5 Ermine Centre, Lancaster Way,
Huntingdon, Cambridgeshire PE29 6XX / UK