GS1 DataMatrix

An introduction and technical overview of the most advanced GS1 Application Identifiers compliant symbology

The crucial guideline to define an application standard according to your sector business needs

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Foreword

While automatic identification is almost a mature technology, it is nevertheless true that the overall system effectiveness assumes a perfect match with the user needs. Yet user needs evolve and in response to these GS1 has incorporated GS1 DataMatrix as a standard data carrier alongside the existing GS1 endorsed linear bar codes.

However, choosing a technology is not enough. We must empower users and implementers of the Automatic Identification Systems to define their business requirements in order to choose the technology best suited to their needs.

This document aims to facilitate this process by offering detailed information on GS1 DataMatrix and its technical characteristics: encoding, printing and reading. This document is the result of the consolidation of technical knowledge of many users on the Data Matrix technology. It aims to be a repository of reference information that can support the implementation of GS1 DataMatrix in any sector, industry or country. This document is not meant to be all inclusive and is not a replacement for any GS1 standard. The GS1 General Specification should always be referred to for all details on GS1 System rules and recommendations.

Who should use this document?

This document provides guidance for the development of GS1 DataMatrix for international usage. This is the responsibility of all content authors, not just the localization group, and is relevant from the very start of development. Ignoring the advices in this document, or relegating it to a later phase in the development, will only add unnecessary costs and resource issues at a later date. The intended audience for this document includes GS1 Member Organization staff, customers, users of the GS1 system and members of working groups developing application standards and guidelines for GS1 system applications.
This document is not the development standard required to develop hardware and software to encode, decode, scan or print GS1 DataMatrix symbology. The technical detail for this level of implementation shall be found in the standard: ISO/IEC 16022, Information technology - Automatic identification and data capture technologies - Data Matrix bar code symbology specification.
This document is not intended as a technical reference for development of imaging (printing and marking), reading (scanning and decoding) and transmission of data technologies. for those who need this level of detail, the standards cited in the bibliography (in particular ISO/IEC 16022) should be implemented.

It is assumed that readers of this document are familiar with bar code applications, are able to create a bar code and understand the basic principles of Automatic Identification and Data Capture. This document limits itself to providing advice related specifically to internationalization.

How to use this document?

GS1 DataMatrix is primarily intended for implementation in an open system (e.g., a system in which the supplier can mark items in the expectation that all trading partners

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will be able to read and correctly interpret the data encoded). In this context, a standard implementation is essential to avoid each partner having to re-label products for different customers and / or at different points of the supply chain.

This guide is designed to help define standard implementations of GS1 DataMatrix. It is a synthesis of recommendations for encoding, printing and reading GS1 DataMatrix.

GS1 has over 30 years experience in the definition, maintenance and management of standards for bar code applications.

Where to get more Information

This document is published on the GS1 web site, www.gs1.org

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1 Introduction to DataMatrix

Data Matrix is a matrix (2D or two-dimensional) bar code which may be printed as a square or rectangular symbol made up of individual dots or squares. This representation is an ordered grid of dark and light dots bordered by a finder pattern. The **finder pattern** is partly used to specify the orientation and structure of the symbol. The data is encoded using a series of dark or light dots based upon a pre-determined size. The minimum size of these dots is known as the **X-dimension**.

Before reading this document one should know the difference between data carrier and data structure. A data carrier A data carrier is a graphical representation of data in a machine readable form; used to enable automatic reading of the Element Strings. Here our data carrier is ISO/IEC Data Matrix (ECC 200) and will be mentioned as "Data Matrix" throughout the document. GS1 DataMatrix is GS1 DataMatrix is the ISO/IEC recognized and standardised implementation of the use of Data Matrix.

1.1 General structure

Data Matrix is composed of two separate parts (see figure below): the **finder pattern**, which is used by the scanner to locate the symbol, and the encoded data itself.

The **finder pattern** defines the shape (square or rectangle), the size, X-dimension and the number of rows and columns in the symbol. It has a function similar to the Auxiliary Pattern (Start, Stop and Centre pattern) in an EAN-13 Bar Code and allows the scanner to identify the symbol as a Data Matrix.

- The solid dark is called the **"L finder pattern"**. It is primarily used to determine the size, orientation and distortion of the symbol.
- The other two sides of the finder pattern are alternating light and dark elements, known as the **"Clock Track"**. This defines the basic structure of the symbol and can also help determine its size and distortion.

The **data** is then encoded in a matrix within the Finder pattern. This is a translation into the binary Data Matrix symbology characters (numeric or alphanumeric).

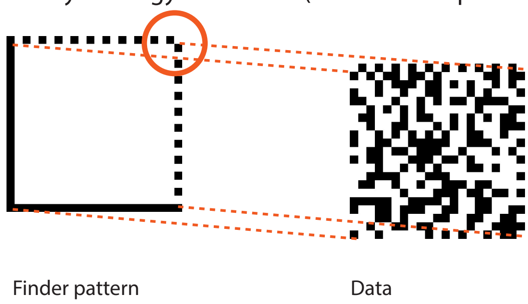

Figure 1.1-1 Finder Pattern and the data

Just like linear (1D) bar codes Data Matrix has a mandatory Quiet Zone. This is a light area around the symbol which must not contain any graphic element which may disrupt reading the bar code. It has a constant width equal to the X-dimension of the symbol on each of the 4 sides.
Each Data Matrix symbol is made up of number of rows and columns. In version ECC 200,

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the number of rows and columns is always an even number. Therefore ECC 200 always has a light "square" in the upper right hand right corner (circled in the figure above). Obviously, this corner will be dark if the Data Matrix symbol is printed in negative (Inverse reflectance printing).

1.2 Technical characteristics

1.2.1 Shape and presentation of the symbol

When implementing Data Matrix, a choice of symbol form must be made (based upon configuration support, available space on the product type, amount of data to encode, the printing process, etc.). It is possible encode the same data in two forms of Data Matrix:

Square **Rectangle**

Figure 1.2.1-1 A square form versus a rectangle form

The square form is the most commonly used and enables the encoding of the largest amount of data according to ISO / IEC 16022 Information technology – Automatic Identification and data capture techniques – Data Matrix bar code symbology specification.

However, the rectangle form may be selected to meet the constraints of speed of printing on the production line. Indeed, the rectangle form with the limited height of the symbol is well suited to some high speed printing techniques And more so to limited or "odd spaced" space constraints.

1.2.2 Size and encoding capabilities

Data Matrix is capable of encoding variable length data. Therefore, the size of the resulting symbol varies according to the amount of data encoded. Accordingly, this section can only estimate the size of a given Data Matrix approximately based on this parameter.

The figure below is extracted from ISO/IEC 16022 (*see A.2, Table of Data Matrix ECC 200 Symbol Attributes*). It provides a useful guide to estimating the size of the symbol but **the exact size of the Data Matrix symbol depends on the exact encoded data. What we mean here is that Data Matrix is composed of fields which have a ladder shape (L shape). See the figure below for the size and capacity graph.**

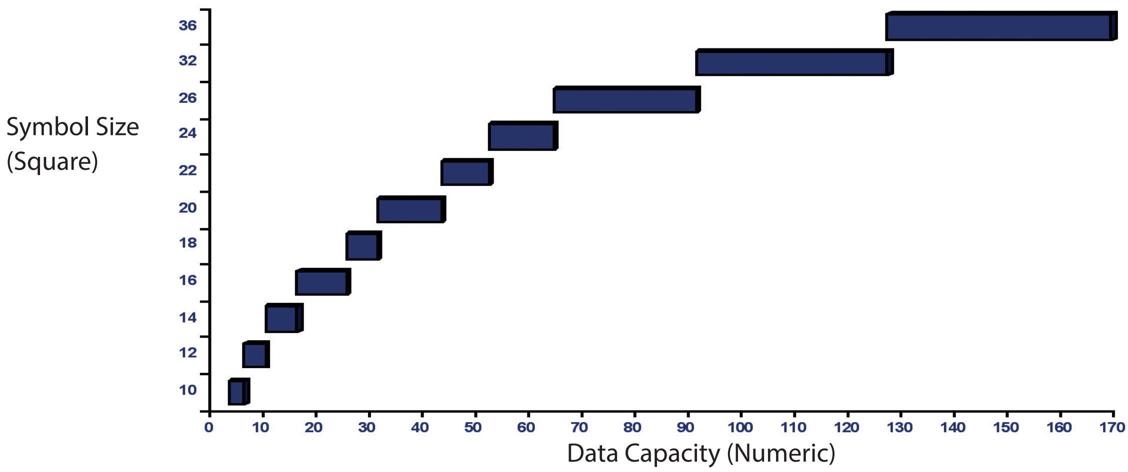

Figure 1.2.2-1 Symbol Size vs. Numeric Capacity

Symbol Size*		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity		% of codewords used for Error Correction	Max. Correctable Codewords
							Num.	Alphanum.		Error/Erasure
Row	Col	Size	No.		Data	Error	Cap.	Cap.		
10	10	8x8	1	8x8	3	5	6	3	62.5	2/0
12	12	10x10	1	10x10	5	7	10	6	58.3	3/0
14	14	12x12	1	12x12	8	10	16	10	55.6	5/7
16	16	14x14	1	14x14	12	12	24	16	50	6/9
18	18	16x16	1	16x16	18	14	36	25	43.8	7/11
20	20	18x18	1	18x18	22	18	44	31	45	9/15
22	22	20x20	1	20x20	30	20	60	43	40	10/17
24	24	22x22	1	22x22	36	24	72	52	40	12/21
26	26	24x24	1	24x24	44	28	88	64	38.9	14/25
32	32	14x14	4	28x28	62	36	124	91	36.7	18/33
36	36	16x16	4	32x32	86	42	172	127	32.8	21/39
40	40	18x18	4	36x36	114	48	228	169	29.6	24/45
44	44	20x20	4	40x40	144	56	288	214	28	28/53
48	48	22x22	4	44x44	174	68	348	259	28.1	34/65
52	52	24x24	4	48x48	204	84	408	304	29.2	42/78
64	64	14x14	16	56x56	280	112	560	418	28.6	56/106
72	72	16x16	16	64x64	368	144	736	550	28.1	72/132
80	80	18x18	16	72x72	456	192	912	682	29.6	96/180
88	88	20x20	16	80x80	576	224	1152	862	28	112/212
96	96	22x22	16	88x88	696	272	1392	1042	28.1	136/260
104	104	24x24	16	96x96	816	336	1632	1222	29.2	168/318
120	120	18x18	36	108x108	1050	408	2100	1573	28	204/390
132	132	20x20	36	120x120	1304	496	2608	1954	27.6	248/472
144	144	22x22	36	132x132	1558	620	3116	2335	28.5	310/590

* Note: Symbol size does not include Quiet Zones.

Table 1.2.2-1 Table of Data Matrix ECC 200 Symbol Attributes (Square form)

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Symbol Size*		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity		% of codewords used for Error Correction	Max. Correctable Codewords
							Num.	Alphanum.		Error/Erasure
Row	Col	Size	No.		Blocks	Cap.	Cap.	Cap.		
8	18	6x16	1	6x16	5	7	10	6	58.3	3/+
8	32	6x14	2	6x28	10	11	20	13	52.4	5/+
12	26	10x24	1	10x24	16	14	32	22	46.7	7/11
12	36	10x16	2	10x32	12	18	44	31	45.0	9/15
16	36	14x16	2	14x32	32	24	64	46	42.9	12/21
16	48	14x22	2	14x44	49	28	98	72	36.4	14/25

* Note: Symbol size does not include Quiet Zones.

Table 1.2.2-2 Table of Data Matrix ECC 200 Symbol Attributes (Rectanbular form)

1.2.2.1 Size and configuration of the symbol

The sizes provided above are given in terms of numbers of rows and columns. For the Data Matrix square-form, the number of rows and columns can vary between 10 and 144 providing 24 different potential symbol sizes.

By contrast for the Data Matrix rectangle-form, however, the number of rows is between 8 and 16 and the number of columns between 18 and 48. The Data Matrix in rectangle-form allows six sizes (the square form has 24) and its use is less widespread than the square-form.

1.2.2.2 The dimensions of the symbol

The dimensions refer to the area used by the Data Matrix symbol, when printed. When printing a Data Matrix the image size is dependent upon the following factors:

- **The amount and format (numeric or alphanumeric) of the encoded information:** numbers and characters are encoded in terms of bits, represented by dark or light "dots" or "modules" of an identical size. The larger the amount of bits required, the larger the symbol will be.
- **The size of the X-dimension** (see techniques for details)
- **The choice of form** : square or rectangular

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1.2.2.3 *Maximum amount of encoded data*

The tables above show the maximum amount of data that can be encoded in the square and rectangular form of Data Matrix. At most, the Data Matrix can encode up to:

- 2,335 alphanumeric characters
- 3,116 numbers

This maximum is based upon a square-form symbol made up of 144 rows and 144 columns divided into 36 ***Data Regions*** of 22 rows and 22 columns each.

For the Data Matrix in the rectangle-form, the maximum capacity is:

- 72 alphanumeric characters
- 98 numbers

A GS1 DataMatrix symbol can encode a sequence of numeric and alphanumeric data, structured according the GS1 Application Identifier rules.

1.2.2.4 *Data Regions*

The matrix symbol (square or rectangle) will be composed of several areas of data (or: **Data Regions**), which together encode the data.

The table below shows an extract of ISO/IEC 16022, which gives details on how the Data Regions are composed. For example a symbol consists of 32 rows and 32 columns, including 4 sub-arrays of 14 rows and 14 columns. The number and size of "sub matrices" within the Data Matrix symbol are shown in the column "Data Region".

Symbol Size (without Quiet Zones)		Data Region		
Row	Column	Size	No.	
24	24	22 x 22	**1**	Symbols with one Data Region
26	26	24 x 24	**1**	
				Changeover Threshold
32	32	14 x 14	**4**	Symbols with more than one Data Region
36	36	16 x16	**4**	

Table 1.2.4-1 Symbol Size vs. Data Region Table

(See **Table 1.2.2-1**, *Data Matrix ECC 200 Symbol Attributes* for the full table*).*

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1.2.2.5 Error Correction

The table below shows the percentage of space used for Error Correction in the Data Matrix symbol and the number of Codewords (data bytes) which may contain an error or be concealed without it being detrimental when scanning and reading the symbol.

Example: Where 80 numeric digits have to be encoded

Symbol Size (without Quiet Zones)		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity			% of Codewords used for Error Correction No.	Max. Correctable Codewords Error/Erasure
							Num.	Alpha-num.	Byte		
Row	Col	Size	No.		Data	Error	Row.	Col.	Size		
26	26	24x24	1	24x24	44	28	88	64	42	38.9	14/25

Table 1.2.5-1 26X26 Data Matrix ECC 200 Symbol Attributes

(See **Table 1.2.2-1**, *Data Matrix ECC 200 Symbol Attributes* for the full table*).*

In the extract above from the ECC 200 Symbol Attributes table of ISO/IEC 16022, we have selected the size of matrix which is equal to, or the next higher than, the amount of data to be encoded – in this case: 88 numeric digits.
Therefore, the matrix is composed of at least 26 rows and 26 columns.

This matrix is made up of 72 **bytes**, which is the sum of the total number of data and error ***Codewords*** shown in the table above (44 +28)

Initially we should know that 2 digits of data make up a byte. It follows that for our example there are 80 numeric digits (40 bytes of data) will be required for the construction the final Data Matrix symbol. From the table above with some calculation, there will be 32 ***Codewords*** for error correction (28 +4, the number 4 comes from subtracting 44 from 40). If the encoded data, irrespective of the encodation scheme in force, does not fill the data capacity of the symbols, pad character (value 129 in ASCII encodation) shall be added to fill the remaining data capacity of the symbol

The actual error correction rate will be: 32/72 = 44.4%. This is higher than the one shown in the table.

Important:
It is recommended to define the size of the Data Matrix symbol by the amount of data to encode and not on the desired percentage of error correction. The amount of data to be encoded generally determines the size of the Data Matrix. However applicable application standards define the best options for a given fixed encodation scheme.

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1.2.3 Error detection methods

There are several methods of error detection. An example is the **check-digit** used by many linear bar codes, which use an algorithm to calculate the last digit of the number encoded. Check-digits can confirm if the string of data is encoded correctly according to the specified algorithm. In the case of a mistake, however, it can't indicate where the mistake was made.

Another example is to repeat data encoded within a symbol, which will help to obtain a successful read even if the symbol is damaged. This is called **redundancy** and can lead to some confusion when applied to Data Matrix: for Data Matrix we will talk about "level of security".

Indeed, the encoding of data in a Data Matrix symbol can be done using multiple ***security levels***. The two-dimensional structure allows the encoding of the data and mechanisms for correcting errors should they occur. These mechanisms enable the scanner to reconstitute some of the information in the event of a damaged or difficult to read Data Matrix symbol. Several security levels are described in the Data Matrix standard ISO/IEC 16022 (Information technology - International Symbology Specification). Each of the Data Matrix code types: ECC 000; ECC 050; ECC 080; ECC 100; and ECC 140 has some form of error detection and correction. ECC that are legacy and no longer used and mentioned here for completeness of description

1.2.4 Reed-Solomon error correction

Data Matrix ECC 200 is the only Data Matrix configuration which employs Reed-Solomon error correction. This feature allows, to a certain extent, the location of errors and, where possible, their correction.

The Reed-Solomon error correction:

- Calculates complementary codes and add-ins during the creation of the symbol,
- Reconstitutes the original encoded data by recalculating the data from the complementary codes and add-ins. The recalculation regenerates the original data by locating errors at the time of scanning. Such errors may be the result of printing problems, specular reflection or degradation of the printed surface.

As outlined above (see *1.2.2.5, Error Correction*), the level of error correction depends on the relative number of error correction Codewords used.

For **GS1 Applications only Data Matrix ECC 200 is specified**. GS1 DataMatrix is the version is the version as defined in ISO/IEC 16022 which supports GS1 Application Identifiers (GS1 AIs) data and the Function 1 symbol character (FNC1). GS1 AIs and FNC1 are required in the GS1 DataMatrix header structure, in this way GS1 DataMatrix is different then from all other Data Matrix versions and other (non-GS1) data encoding methods.

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1.3 Recommendations in general for defining application standards

Achieving an effective business implementation of any technology depends on correctly matching the features of technology to the user needs. For Data Matrix special attention is required to clearly articulate the user needs as well as setting the business objectives reasonable and achievable.

When developing application standards for Data Matrix, users must meet to agree on:

- The mandatory data (GS1 Application Identifiers) to be encoded, For example, if it is agreed that the business need is met by encoding between 20 and 40 digits of numeric data, then a Data Matrix symbol with 20 rows and 20 columns will meet the need.
- The shape of the Data Matrix: square or rectangle. Indeed, both square and rectangle forms could be an option.
- The level of security. For GS1 Applications only Data Matrix ECC 200 is specified and the level of security is given.

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2 Encoding data

The sub-sections below outline the various methods that exist for encoding data into Data Matrix symbols. All methods used to generate the Data Matrix symbol require the data to be submitted in a form that is understandable to the encoder.

2.1 The encoding structures

The general version Data Matrix supports various encoding structures which can be used in the same symbol simultaneously. Examples include: ASCII, ISO/IEC 646, C40, Text, X12, EDIFACT and Base 256. These structures provide an opportunity to maximize efficiency of encoding the required data in a Data Matrix symbol.

The simplest solution, and the one mandated by the GS1 standards, is to encode data using the subset of ISO/IEC 646 (equivalent to ASCII table 256) for all the information. This limited character set is supported by almost all computer systems available around the world today. It is strongly recommended to make ISO/IEC 646 (or the equivalent ASCII 256) the default option.

ISO/IEC 646 is derived from the **ASCII** (American Standard Code for Information Interchange) that was first established in the 1960s as the standard way for the binary representation of digits and the characters in the Latin alphabet. For example, the character "a" is associated with "01100001" and "A" to "01000001" in the standard ASCII256. This enabled digital devices to communicate with each other and to process, store, and communicate character-oriented information. In particular, almost all personal computers and computer like devices in the world started adopting ASCII encoding.

Although ASCII coding is now supplemented by additional characters, known as extensions, to support computers encoding characters that are not used in America such as accented characters "à", "ô" or "é") these are not allowed for use within the GS1 System. This is not because Data Matrix is unable to encode these characters, but for global use ambiguity may arise due to:

- the same ASCII code being used for different extensions in different geographical regions
- the inability of many users to key enter the extensions (due to computer limitations and human factors).

When encoding data in accordance with the GS1 System using GS1 DataMatrix, three principle rules apply:

a. The Data Matrix must have a leading FNC1 character in the first position to indicate that the symbol is GS1 DataMatrix. FNC1 is a special, non-printable, character. It is often inserted using a double-byte "Latch to extended ASCII" but this is system dependent.

b. The GS1 Application Identifiers (or AIs) are used for all encoded data (see *Section 2.2. GS1 Element Strings*).

c. Only the characters contained in ISO 646 subset may be used. It should be noted that spaces can not be encoded (see *A.4, The International Standard ISO/IEC 646 for representation of each character*).

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2.2 GS1 Element Strings

Although it is possible to encode any type of data in the general Data Matrix, when using GS1 DataMatrix the data must be structured according to the rules of the GS1 System. Element strings begin with an Application Identifier which is then followed by the data that the AI denotes. The system can be characterized by:

- A standard format for **encoding data** and **bar coding** specifications.
- A **symbol architecture** that allows multiple data elements (item identification, expiration date, batch number, etc.) within a single bar code.

These features enable trading partner information systems to be developed in a way that enables communication via encoding and decoding the information in the GS1 DataMatrix symbol.

GS1 Application Identifiers (AIs) are 2, 3 or 4 digit numbers which define the meaning and the format of the data that follows. Each AI and its associated data can be encoded into a GS1 DataMatrix symbol in the same way – and using the same logical rules - as encoding data in the linear bar code symbol GS1-128. Application Identifiers should be clearly recognisable to facilitate key entry. This is achieved by putting parentheses around Application Identifiers in the Human Readable Interpretation under the symbol. **The parentheses are not part of the data and must not be encoded in the bar code.**

This table shows the typical GS1 element strings.:

AI	Data Definition	Format (AI / data)*
01	GTIN	n2+n14
10	Batch or Lot Number	n2+an..20
11	Production Date (YYMMDD)	n2+n6
15	Best Before Date (YYMMDD)	n2+n6
17	Expiration Date (YYMMDD)	n2+n6
21	Serial Number	n2+an..20

Table 2.2-1 GS1 Element Strings

* Meaning of the abbreviations used:

n	Numeric digit
an	Alphanumeric characters
n2	Fixed length of two numeric digits
an…20	Variable length with a maximum of 20 alphanumeric characters

Table 2.2-2 Abreviations

A complete list of Application Identifiers can be found in *A.1, Full list of GS1 Application Identifiers in numerical order.*

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2.2.1 Function 1 Symbol Character (FNC1)

By definition in ISO/IEC 16022 GS1 DataMatrix uses a special start sequence to differentiate GS1 DataMatrix from other ISO/IEC Data Matrix symbols. This is achieved by using the Function 1 Symbol Character (FNC1) in the first position of the data encoded. It enables scanners to process the information according to the GS1 System Rules.

The FNC1 (ASCII 232) is encoded in two separate ways within GS1 DataMatrix:

- Start character
- Field Separator (to seperate varible length article identifiers)

Important:
In accordance with ISO/IEC 15424 - Data Carrier Identifiers (including Symbology Identifiers), the Symbology Identifier (the first three characters transmitted by the scanner indicating symbology type)]d2 specifies that the symbol read is a GS1 DataMatrix symbol.

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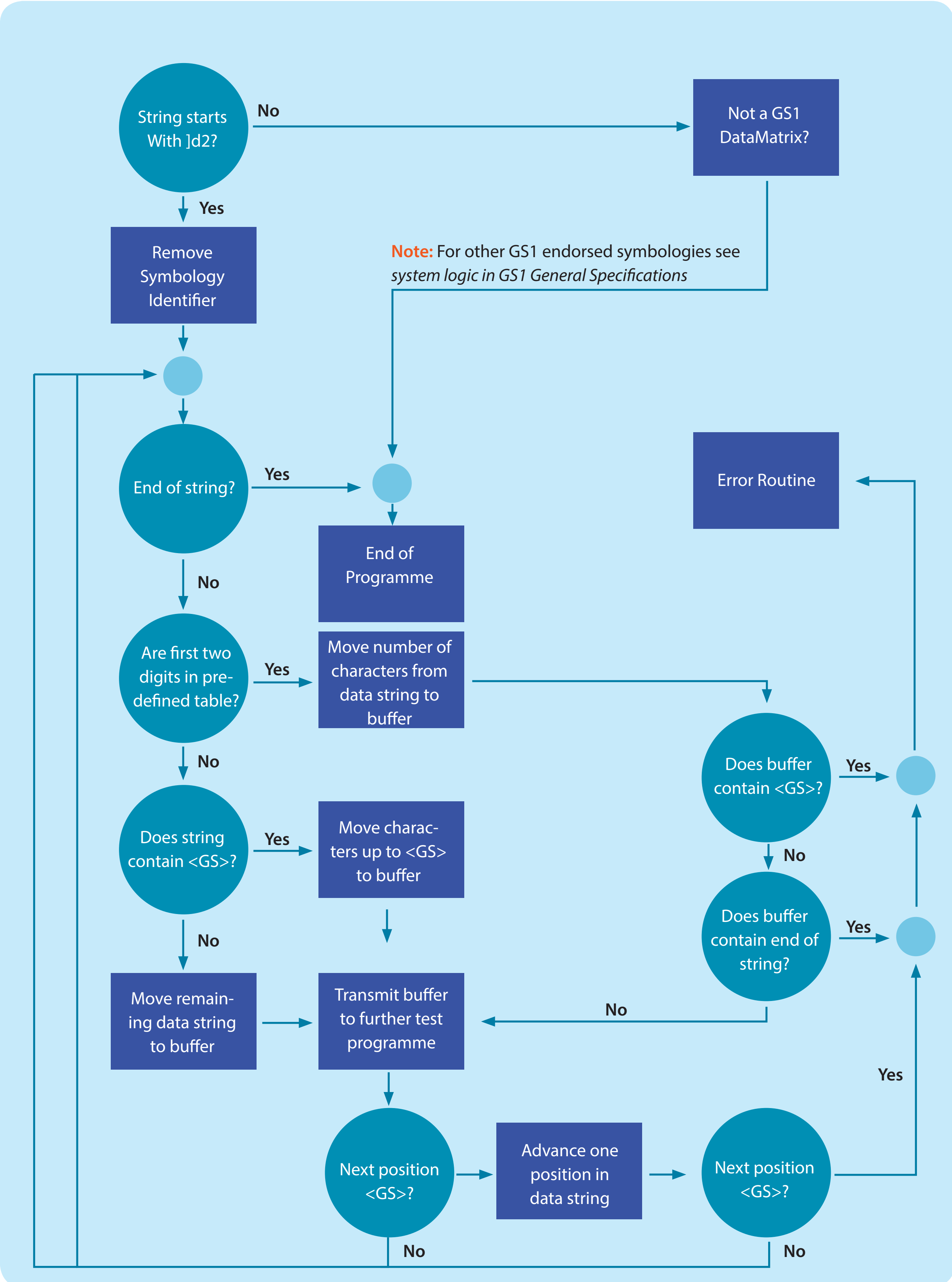

Figure 2.2.1-1 Processing of Data from a scanned GS1 DataMatrix Symbol

2.2.2 Concatenation

Using GS1 DataMatrix, it is possible to concatenate (chain together) discrete Application Identifier (AIs) and their data into a single symbol. When the AI data is of **pre-defined length**, no field separator is required when the next Application Identifier and data are concatenated immediately after the last character of the previous AI data. Where the AI data is not of pre-defined length, it must be followed by a field separator when concatenating more AIs. The FNC1 character acts as field separator. The FNC1 is the character that has the codeword ASCII value 232. A FNC1 separator is not required after the last AI and last data encoded in the symbol independent of whether the field is of pre-defined length or not.

Example:

- The data 1, 2 and 3 is represented by the Application Identifiers AI 1, AI 2, and AI 3.
- The AI 1 is of pre-defined length (see *table in 2.2.3, Pre-defined length vs. fixed length*)
- The AI 2 and 3 are not pre-defined (e.g., they contain variable length data)
- FNC1 is used to represent the Function 1 Symbol Character.

Concatenation of the Data 1 and 2 :

FNC1	AI 1	Data 1 (pre-defined length)	AI 2	Data 2 (variable length)

Concatenation of the Data 2 and 3:

FNC1	AI 2	Data 2 (variable length)	FNC1[1]	AI 3	Data 3 (variable length)

Concatenation of the Data 1, 2 and 3:

FNC1	AI 1	*Data 1 (pre-defined length)*	AI 2	*Data 2 (variable length)*	FNC1[1]	AI 3	*Data 3 (variable length)*

When several GS1 Application Identifiers have to be concatenated and only one of them is of variable length, it is strongly recommended to position it at the end of the symbol. This optimises the size of the symbol by avoiding the use of a separator character.

2.2.3 Pre-defined length vs. fixed length element strings

A common mistake is to believe that any GS1 Application Identifier with a fixed data field is never followed by a FNC1 separator when concatenated. In fact, there is a table which defines the fixed data fields. This table shows every GS1 Application Identifier published when they were first introduced. This table has never been amended and there is no intention to change it in the future. It enables software decoders to be built without the risk of them having to be modified by the publication of new GS1 Application Identifiers. This table should be included in any processing software which is intended to process GS1 AIs.

The numbers in parentheses are not yet allocated. They were placed in reserve and maybe, in the future, will be allocated to new GS1 AIs with a pre-defined length.

[1] When FNC1 used as a separator, the scanner must transfer the FNC1 character as a field separator <GS>.

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For all GS1 AIs that start with two digits that are not included in this table, it is mandatory to follow the data with the field separator FNC1 if it is not the last data encoded in the symbol.

First 2-digits of the GS1 Application Identifier (AI)	Number of digits (AI and Data Field)	First 2-digits of the GS1 Application Identifier (AI)	Number of digits (AI and Data Field)
00	20	17	8
01	16	(18)*	8
02	16	(19)*	8
(03)*	16	20	4
(04)*	18	31	10
11	8	32	10
12	8	33	10
13	8	34	10
(14)*	8	35	10
15	8	36	10
(16)*	8	41	16

Table 2.2.2-1 Pre-defined fixed length data field Application Identifiers

**These Application Identifiers are reserved for future assignment.*

Example :

Some AIs are defined as having a fixed length data field, but they are not included in the initial table of pre-defined length above. In these cases, the data encoded after the AI must be followed by a field separator FNC1 when other AIs are concatenated after it in a GS1 DataMatrix. This is true, even if the AI data has a fixed length. One example is AI (426), used to indicate the country of origin and which has a 3-digit fixed length data field.

2.3 Human Readable Interpretation

It is common sense to have Human Readable Interpretation of the Application Identifiers (AIs) and their associated data near the GS1 DataMatrix Symbol in which they are encoded. The precise location and font used for the Human Readable Interpretation determined by the specific application guidelines (see *1.3, Recommendations in general for defining application standards*). Typical conventions place the primary information, such as the Global Trade Item Number (GTIN), in the human readable data underneath the bar code. The characters, however, should be clearly legible and must be obviously associated with the symbol.

Application Identifiers (AIs) should be clearly recognisable within the Human Readable Interpretation to facilitate key entry in the event that the symbol can not be scanned. This is achieved by putting the AI between parentheses. The **parentheses are not part of the data and are not encoded in the symbol**. This is in clear contrast to the use of the FNC1 which must be encoded in the symbol, when used as a start or separate character, but never appears in the Human Readable Interpretation.

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The following examples show the encoded data in the GS1 DataMatrix and how the Human Readable Interpretation could appear:

Example 1: FNC101034531200000111709112510ABCD1234

(01)03453120000011(17)091125(10)ABCD1234

Figure 2.3-1 Example 1

Example 2: FNC101950110102091717120508 10ABCD1234 FNC14109501101020917

(01)03453120000011(17)120508(10)ABCD1234(410)9501101020917

Figure 2.3-2 Example 2

Example 3: FNC101034531200000111712112510ABCD1234

The Human Readable Interpretation may also use legible text instead of the AI digits using the standardised Data Titles. This, along with the permissible location of the Human Readables, should be set by the application guideline:

GTIN(01): 03453120000011
EXPIRY(17): 2012-11-25 (yyyy-mm-dd)
BATCH/LOT(10): ABCD1234

Figure 2.3-3 Example 3

Always refer to the GS1 General Specification for complete rules and recommendations on the application and use of Human Readable Interpretation.

2.4 Symbol location

The exact location of a GS1 DataMatrix symbol on a product is **determined by the manufacturer** who will need to consider: (see Section 6 of the GS1 General Specifications for more details)

- The available space on the product package
- The type of product and printing substrate (packaging material)
- The intended usage of the GS1 DataMatrix (for example, will the symbol be read in an automated environment or by hand)

It is also necessary to ensure that the **Quiet Zone** around the symbol is protected. The Quiet Zone is the area around the symbol that shall be free from any print matter with a width

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that must be greater than or equal to the size of the symbols **X-dimension** (See *1.1, General structure*).
Other packaging constraints can also greatly affect the reading of the symbol. For example folds or seams in the packaging, curvature (e.g., blister packs), etc. can all impact scanning and should be considered when selecting the most appropriate symbol location. This is especially important when printing very small GS1 DataMatrix symbols.

It should be noted, however, that thanks to its intrinsic properties, the orientation of the symbol has no impact on scanning performance.

Exp. Date: Nov. 25, 2009

Batch nb: ABCD1234

03453120000011

GTIN(01) : 0345312000011

Figure 2.4-1 Rectangular form Example

2.5 Recommendations on encoding for defining application standards

In terms of encoding data, the application standard must specify the following:

- The Data Matrix syntax and encoding rules. For GS1 Applications, this syntax is already subject to technical specifications defined and recognized (ECC 200 with leading FNC1 and GS1 Application Identifiers)
- Which Application Identifiers (AIs) to use (mandatory and optional),
- Location and format of Human Readable Interpretation
- If necessary, symbol placement determined by the area of application Examples of areas of application could include: direct part marking of surgical instruments, unit-dose pharmaceuticals, logistic applications, etc.

An example of a detailed application guideline, from the IFAH, is shown in *A.8, Application Standard IFAH*

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3 Symbol marking techniques

This section provides an overview of the main technologies and the main processes for printing GS1 DataMatrix. It summarises their individual strengths and weaknesses for various applications. It **does not** aim to compare or promote a particular technology.

The focus is mainly on technologies that can be used on-demand: that is to say, systems that can encode dynamic information such as batch numbers or serial numbers. Therefore, it does not detail other conventional techniques such as flexographic or offset which are excellent for printing static information (e.g. product identification).

Please also bear in mind that the technologies and materials for printing and marking GS1 DataMatrix are developing fast. It is therefore advisable to consult with your local GS1 Member Organisation and technical partners to take advantage of the latest developments.

3.1 Basic software functions

Software of some type will be required to generate GS1 DataMatrix symbols. The software can format the data into syntax required by the printing device and often can control the printing materials too. Software can be purchased that is integrated into the printing device or that is external and separate from it.

3.1.1 Printing Device Independent Software

In principle, this type of software can be used with any type of printing device or indeed several different ones simultaneously.

The concept is to generate information to be printed and transfer this to the printer either by:

- sending the print-file message to the printer, or,
- creating an image that can be reproduced

3.1.2 Software embedded in the printing device

This type of software is characterized by a printing device having a dedicated internal logic that directly generates the GS1 DataMatrix symbol to be printed.

This is particularly useful when the data contained and/or size and form of the symbol to be printed vary from one product to the next. Indeed, the computing time can be minimized by using software integrated with the printing device by, for example, having the device generate a unique number for each product (e.g., a serial number).

3.1.3 Selecting the right software

The exact choice of software will need to meet the individual business requirements. In general terms the software must be capable of generating a GS1 DataMatrix symbol in full

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conformance to the ISO/IEC 16022 standard. Often a difficult area is the programming of FNC1 in first position as each software supplier has (or has not) developed its own method to obtain the correct encoding in the form of ASCII 232. It is worth ensuring the software has this feature. The software should also allow for special characters:

Many of the good software programmes provide a 'wizard' that helps to check and automate the encoding of data according to the GS1 standards (e.g., Application Identifiers, data formats, check-digits, etc).

3.2 Symbol marking technologies

This section only focuses on technologies that can be used 'on-demand': that is to say, systems that can encode dynamic information such as batch numbers or serial numbers. Therefore, it does not detail other conventional techniques such as flexographic or offset which are excellent for printing static information (e.g. product identification).

The symbol marking technologies most suited to printing GS1 DataMatrix are:

- Thermal transfer
- Inkjet
- Laser etch
- Direct part marking (dot-peening, engraving, etc.)

… the exact choice will primarily be made in terms of the available support material and exact business requirement.

Particular attention is required when specifying the minimum size of the X-dimension and the ability of the print substrate to support it. The target size of the X-dimension is likely to be an important consideration in the choice of printing system.

3.2.1 Thermal transfer

Thermal transfer printing is one of the most widely used technology for printing on-demand bar code labels. The technology works through heat being transmitted onto a ribbon (a tape coated with specially designed ink) that then transfers the image to the label. Very good quality bar codes can be achieved when the labeling material and print ribbon are fully compatible.

The choice of ribbon to be used is therefore normally determined by the:

- Substrate - its ability to absorb ink and its smoothness,
- Marking system - print head configuration and the print speed

The normal print resolution for thermal transfer printers is between 100 and 600 dpi (dots-per-inch).

A wide variety of thermal transfer ribbons are available and it is very important to match your ribbon selection to the printer. Print quality will also be influenced by heating energy, printing speed and pressure.

The quality of printed symbols must be checked at regular intervals. One of the main

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problem areas with thermal transfer printing is the risk of a 'print-head burnout' where one of the heating elements stops working so creating gaps

3.2.2 Inkjet

Inkjet is a printing process that does not require contact between the printer and the substrate. The technology works by propelling tiny drops of ink onto the substrate to create the symbol. There are two main categories of InkJet printer:

- ***Continuous Inkjet:*** A high-pressure pump creating a continuous stream of ink droplets that are then subjected to an electrostatic field. This results in a controlled, variable electrostatic charge that determines if the ink drop should be printed on the substrate or recycled (leaving a light area).

- ***Drops on Demand:*** Printers in this family only use drops of ink that are required to print. It is particularly suited to high resolution printing.

The print head needs to be close to the substrate (some products can print from a distant as far as 20 mm) and it is suitable for printing on a variety of media and substrates.

Inkjet printing usually prints edges in an irregular shape. This is caused by the absorbency of the substrate and by the irregular shape of the single dots. Good quality symbols are possible when printing on a suitable substrate, using a high resolution printer and fast drying ink. Also, if the Inkjet printer is not kept within the operating parameters recommended by the manufacturer, this can cause quality issues.

Special attention must be paid to the consistency of the speed with which the object to be printed passes the print head. Precision is required to ensure quality symbols.

Example: A GS1 DataMatrix printed using Continuous Inkjet :

Figure 3.2.2-1 Inkjet printed GS1 DataMatrix

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3.2.3 Laser Etch (Direct Part Marking -DPM)

Laser etch – or laser engraving – uses precisely controlled lasers to engrave or mark the bar code on the product. The high concentration of laser power burns or etches the symbol and this needs a computer using a series of mirrors and lenses to focus the laser. The process allows a product to be directly and permanently marked but is only suitable for "laserable" materials.

The power of the laser needs to be set based on the volume printing required as well as the speed of printing. The power must be adapted to substrates and commonly ranges from 10 to 100 watts.

Example: A GS1 DataMatrix printed using Laser:

Figure 3.2.3-1 GS1 DataMatrix Laser symbol

3.2.4 Dot Peen (Direct Part Marking -DPM)

The technology is used to directly mark the material and is particular suitable for solid materials (metals, plastics, wood, etc.…). It can be used for all the information to be marked on the item (text, date, logo, etc.) as well as the GS1 DataMatrix symbol. A small head – normally made from a very strong material such as tungsten – is computer controlled to make a defined series of identical punch marks in the surface of the substrate. The depth of marking can be carefully controlled to ensure all indents are identical making this technique particular suited for printing GS1 DataMatrix directly on items made of metal or other material with very hard flat surfaces.

Example: A GS1 DataMatrix printed using Direct Part Marking:

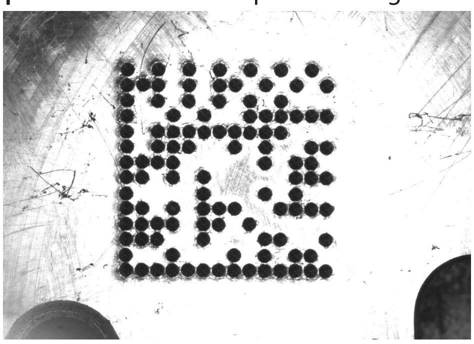

Figure 3.2.3-1 GS1 DataMatrix dot-peen symbol

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3.3 Selecting the right symbol marking technology

The technology chosen for a given application should take into account the **internal environment** including factors such as **substrate.**

The table below gives an indication of the compatibility between the substrate (the material upon which the GS1 DataMatrix will be printed) and symbol marking technologies. In all cases, it is recommended to test and confirm that the technology will work in the real environment where it will be used. This testing should include all aspects of the technology including inks, varnishes, maintenance cycle, etc.

Substrate / Technology	Paper	Corrugated	Glass	Plastic	Metal
Inkjet	Yes	Yes	Yes	Yes	Yes
Laser Etch	For specific colours *or* specific finishing	For specific colours *or* specific finishing	under certain conditions	If contrast can be achieved *or* specific finishing	Painted *or* oxidised
Thermal transfer (on-demand)	Useful for adhesive labels	No	No	Plastic films	No
YAG Laser	Coloured background *or* specific finishing	Coloured background *or* specific finishing	No	Yes	Yes
Ink jet (on-demand)	Yes	Yes	No	No	No
Direct Part Marking	Film transfer	Film transfer	No	Yes	Yes

- **Available space for printing**

Table 3.3-1 Substrate / Marking Technology Table

The physical size of the symbol and all related Human Readable Information must take into account the space available to print them. In general terms, larger symbols will have a better scanning and printing performance than smaller ones but many factors – including legally required safety information – will impact the space available for printing the bar code.

- **Printing speed**

When printing symbols on-line (e.g., as part of the production line process for items), the speed of the overall product line will have a big influence on the choice of technology selected.

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The technology chosen will also be impacted by **external factors** such as:

- **Sector norms and conventions** (e.g., healthcare, automotive, aeronautical, etc.)

Many sectors have norms and conventions for the use of Data Matrix in terms of quality, symbol location, required data (both encoded and in Human Readable Interpretation). These industry norms should be considered when selecting the symbol marking technology.

For example, in the healthcare sector, the user community has agreed on a permissible x-dimension for small healthcare products (see *Annex 3: GS1 size recommendations for symbols using Data Matrix*).

- **Customer requirements**

As in all business transactions, the needs of the customer should be taken into account. Some customers may impose a set of specifications as a requirement for doing business. These specifications may favour one technology over others. For example, by setting an extremely high minimum quality verification threshold (see *3.6 Verification of symbol (Data and Print Quality)*) the customer may in effect be imposing a given printing technology.

Within the open environment where GS1 standards are used, it is very important for all players to work to industry established standards. This creates a critical mass of particular usages and reduces overall costs as many competing technology providers work to meet the common requirements.

- **Regulatory requirements**

In some highly regulated industries (such as healthcare or aerospace) and/or in some countries, regulations may be in place. The technology's ability to meet these regulatory requirements will then be a key consideration when making a purchase.

3.4 General recommendations for symbol quality

Symbol quality is of great importance and should be included in any production quality control process. As a quick check the following should be confirmed with any technology supplier:

- Full compliance to the ISO/IEC 16022 standard
- The software is able to support GS1 Application Identifiers
- Data Matrix ECC 200 (not older, obsolete versions of Data Matrix) is supported
- The FNC1 is supported both as a start and separator character

As outlined earlier (see *General structure*) the size of the GS1 DataMatrix symbol can vary. In general terms, larger X dimension symbols will have a better scanning and printing performance than smaller ones but many factors (available space, amount of data encoded, etc.) will influence the size of symbol.

It is of critical importance for the final quality of the printed symbol that the ability of the printer to achieve the selected X-dimension.

→ **Note:** The print-head individual print element size will determine which X-dimensions can and cannot be achieved.

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3.5 Colors and contrast

Contrast is the technical name for the difference between the dark and light areas in a bar code and, in particular, how the difference is seen by the scanner. It is imperative that the printing process ensures the ease with which the scanner can discriminate clearly between the dark areas and light areas of the symbol. Indeed, without this the symbol will not scan.

Contrast is heavily impacted by the colour and reflectance of the substrate used. When implementing GS1 DataMatrix it is therefore necessary to think about the colours used for both substrate and inks (if used).

These simple recommendations should help selecting a good colour combination and achieving good symbol contrast:

- Use of Black and White in printing is generally accepted as the best colour combination. (It should be noted that one feature of Data Matrix is that the colours can be reversed: light modules on a dark background or dark modules on a light background. When using this reverse / inverse image feature scanner / imager capability to read reverse / inverse images should be noted.
- Dark areas should use solid dark colours (black, blue, or colours that contain a very high proportion of black).
- Light areas should use bright and reflective colours (white, yellow or red (note some scanners use a red-light therefore red appears 'white' to the scanner).
- Intermediate colours or hues – those that appear neither light nor dark – should not be used
- Certain substrate materials, particularly highly reflective metals, and highly reflective inks (e.g., gold or silver) should be avoided as the reflectance can 'blind' the scanner.

Some common contrast problems are caused by:

- A bad choice of colours for the dark and/or light areas.
- The use of a transparent background (known as 'Opacity')
- A 'blurring' of the dark colours into the light area.
- Excessive reflectance from very shinny or glossy surfaces.

3.6 Verification of symbol (Data and Print Quality)

This section highlights those parameters that can affect the overall symbol quality and how they can be checked or verified. It is important to stress that quality covers both:

- Conformance of the encoded data (e.g., correct use of GS1 Application Identifiers, Check-Digits, etc.)
- Symbol Print Quality (e.g., according to ISO/IEC 15415).

Quality should not be seen as a simple check at the end of the process, but quality should be built into the development process with the appropriate conformance checks made at each stage. It is also important to verify that the final printed symbol meets the requirements of the appropriate application standard in terms of encoded data, print quality, symbol size, symbol location, etc.

An example of a detailed application guideline, from the IFAH, is shown in *A.7, Application Standard IFAH.*

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3.6.1 ISO/IEC 15415 Bar code print quality test specification – two dimensional symbols

3.6.1.1 Print quality testing methodology(See Section 5.5 of the GS1 General Specifications - Bar Code Production and Quality Assurance)

ISO/IEC 15415 and GS1 General Specifications define the methodology to test the print quality of printed GS1 DataMatrix symbols. Under this methodology the symbol grade is only meaningful if it is reported in conjunction with the illumination and aperture used expressed as:

grade/aperture/light/angle [2]

Grade : is the overall symbol grade as defined in ISO/IEC 15415. It is a numeric grade (4 being the best and 0 the worst). ISO/IEC 15415 was based upon – and is fully compatible with – an ANSI verification methodology. One of the main differences is that ISO/IEC 15415 uses a numeric grading structure, expressed up to one decimal place, while ANSI used a scale of A to F. The conversion between the two grading systems is summarized as:

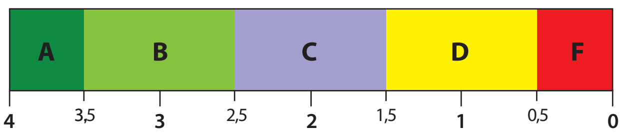

Figure 3.6.1-1 Symbol Grade in ISO/IEC 15415

Aperture: is the aperture reference number defined in ISO/IEC 15416 (or expressed in mils or thousandths of an inch)

Light: defines the illumination: a numeric value indicates the peak light wavelength in nanometres (for narrow band illumination); the alphabetic character W indicates that the symbol has been measured with broadband illumination ("white light") but for GS1 Applications 670 +/- 10 nm is the norm.

Light sources for bar code scanning applications normally fall into two areas:
narrow band illumination in either the visible or the infra-red spectrum, or broadband illumination covering a large part of the visible spectrum, sometimes referred to as "white light" although it may have a bias to a colour; a very few specialized applications may call for light sources of unusual characteristics such as ultra-violet for fluorescent symbols.

Multi-row bar code scanning almost always uses narrow band visible light, with light sources with a peak wavelength in the red part of the spectrum, between 620 and 700 nm. Infra-red scanning uses sources with peak wavelengths between 720 nm and 940 nm.

Two-dimensional matrix symbols are scanned under a variety of illumination conditions, with the most common being white light and, in a number of hand-held reading devices, the same visible red area of the spectrum as for linear and multi-row bar code symbols.
The most common light sources used for these purposes are:

[1] Angle: is an additional parameter defining the angle of incidence (relative to the plane of the symbol) of the illumination. It is only required in the overall symbol grade if is different from 45°. All GS1 Application Guidelines specify a 45° angle.

a) Narrow band
   1) Helium-neon laser (633 nm) (multi-row bar code symbols only).
   2) Light-emitting diode (near-monochromatic, at numerous visible and infra-red peak wavelengths).
   3) Solid-state laser diode (most usually 660 nm and 670 nm) (multi-row bar code symbols only).

b) Broadband
   1) Incandescent lamp (nominally white light with a colour temperature in the range 2 800°K to 3200 °K).
   2) Fluorescent lighting (nominally white light with a colour temperature in the range of 3200 °K to 5500 °K).

Example: A print quality test carried out with an aperture of 10 mils, a light source of 670 nm and at an angle of 45° gave the grade of 2.7(B). The results should be expressed as:

2.7/10/670

3.6.1.2 Parameters measured and their significance

ISO Symbol Grade: The overall ISO symbol grade is the most important parameter for communicating the print quality of a symbol. The scan grade is the lowest grade achieved for seven parameters which are Symbol Contrast, Modulation, Fixed Pattern Damage, Decode, Axial Nonuniformity, Grid Nonuniformity Unused Error Correction and any others specified for a given symbology or application, and the overall ISO symbol grade is the arithmetic mean of the individual scan grades for a number of tested images of the symbol.

Decode: This is the first step in the verification and applies the reference decode algorithm - the set of rules/steps for decoding the symbol defined in ISO/IEC 16022 - to the elements seen by the verifier. If a valid decode results, the decode parameter passes and is given grade 4, otherwise it fails (grade 0).

Symbol Contrast: The Symbol Contrast is the difference between the highest and the lowest reflectance values in the profile – in simple terms the difference between the dark and light areas (including the quiet zones) as seen by the scanner. Symbol contrast is graded on a scale of 4 to 0.

Figure 3.6.1.2-1 *A symbol with very poor Symbol Contrast.*

Modulation: Modulation is related to Symbol Contrast in the sense that it measures the consistency of the reflectance of dark to light areas throughout the symbol

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Figure 3.6.1.2-2 A Symbol with poor Moduation caused by irregular dark areas

Axial Nonuniformity: measures and grades (on the 4 to 0 scale) the spacing of the mapping centres and tests for uneven scaling of the symbol along the X or Y axis.

Grid Nonuniformity: Measures and grades (on the 4 to 0 scale) the largest vector deviation of the grid intersections, determined by the theoretical position prescribed by the reference decode algorithm and the actual measured result.

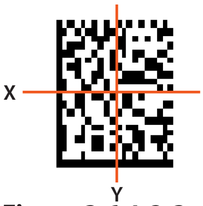

Figure 3.6.1.2-3 An Axial Nonuniformity problem

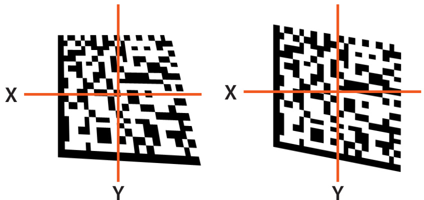

Figure 3.6.1.2-4 A Grid Nonuniformity problem

Unused Error Correction: measures and grades (on the 4 to 0 scale) the reading safety margin that error correction provides. Unused error correction indicates the amount of available Error Correction in a symbol. Error Correction is a method of reconstructing data that is lost via damages or erasure of the symbol. Error correction may have to be used to decode the symbol and may have been caused by damage to the symbol or poor printing. 100% unused Error Correction is the ideal case.

Fixed Pattern Damage: measures and grades (on the 4 to 0 scale) any damage to the finder pattern, quiet zone and clock track in the symbol. The example below highlights the areas of the symbol that are tested under these parameters by showing the various defects:

Figure 3.6.1.2-5 Fixed Pattern Damage

The example shows defects in the L-Shaped Finder Pattern and in the Clock-Track:

- **L1:** Irregular L-Shaped Finder Pattern on the left
- **L2:** Irregular L-Shaped Finder Pattern on the lower edge
- **QZL1:** Note : the issue of L1, also means the Quiet Zone on the left is irregular
- **QZL2:** Note : the issue of L2, also means the Quiet Zone as the bottom is irregular
- **OCTASA** (Overall Clock Track and Adjacent Solid Area): Issues in the Clock Track (the dotted line opposite the L-Shaped Finder Pattern) can take one of three forms:
  - **CTR** (Clock Track Regularity test): A pass/fail test on the elements that make up the Clock Track;
  - **SFP** (Solid Fixed Pattern test) : A graded measure (on a 4 to 0 scale) measure of the dark and light areas of the Clock Track
  - **TR** (Transition Ratio). A graded measure (on a 4 to 0 scale) measure of the sequencing of the dark and light areas of the Clock Track

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- **Average Grade:** In addition to the assessment of the individual tests above (which are very useful for symbol diagnostics), an Average Grade can be reported that takes into account the cumulative effect of any damage. It is calculated using the results of L1, L2, QZL1, QZL2 and OCTASA together. This is particularly useful as, collectively, when combined, many small errors may cause scanning problems.

Print growth: Print growth is not a graded parameter but should be a very informative measure for the purposes of process control. It is a measure of how symbols may have grown or shrunk from target size. If the growth or shrinkage is too large, then scanning performance will be impacted.

Print growth may be measured and evaluated independently on both the X and Y axis to assess both horizontal and vertical growth. The two examples below show:

Figure 3.6.1.2-6 Too much Print Growth

Figure 3.6.1.2-7 Where Print Growth has been underestimated

3.6.2 *Other Print Quality Standards*

ISO/IEC 15415 and ISO/IEC 29158:2011 are for measuring the print quality of GS1 DataMatrix symbols. However, there are number of other emerging quality standards for Data Matrix including, AS9132 and AIM DPM. They were developed primarily for direct part marking (DMP) and their main features are described below for information purposes only.

3.6.2.1 AS 9132

AS (American Standard) 9132 deals with general print quality for part marking. It is referenced by a number of aeronautical companies that require 2D symbols to be used by their suppliers. The main print quality features are:

Angle of distortion:

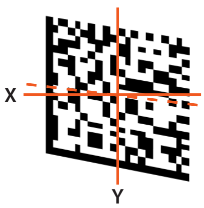

Figure 3.6.2-1 Angle Distortion

This figure above shows how distortion is measured. The standard allows a distortion up to 7°.

Filled Cells:

This is a measure, expressed as a percentage of the filled cells versus the ideal as given by symbology specifications

Figure 3.6.2-2 Filled Cells

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This example shows marked cells which have been filled (when they should not have been) as a result of the print process used. The error correction capabilities of DataMatrix allow such symbols can often to be decoded if the error is not too large.

Centre Point Discrepancy:
Slight discrepancy can occur between the actual centre of a cell and its theoretical position. Centre Point Discrepancy measures any deviation in this area:

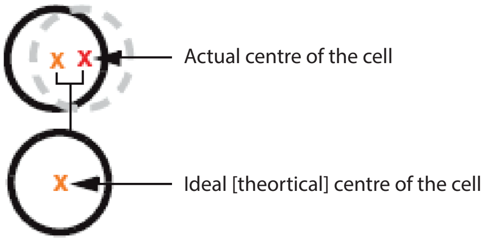

Figure 3.6.2-3 Centre Point Discrepancy

Elongation:

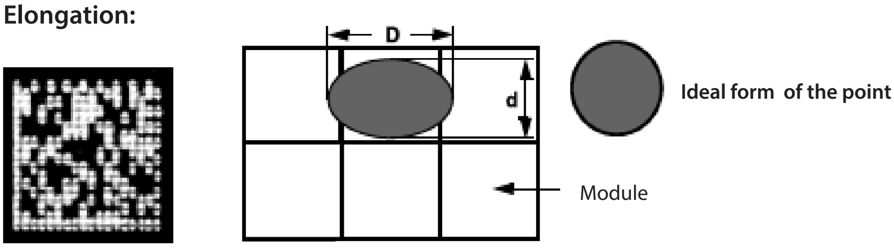

Figure 3.6.2-4 Elongation

Elongation of individual cells may occur due to a variety of printing conditions. Elongation is measured as a deviation from the perfect circle. The standard allows for a 20% difference between D and d.

Number of dots per element:

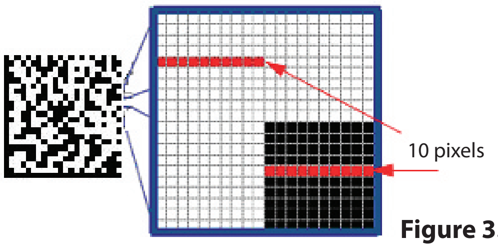

Figure 3.6.2-5 Number of dots per element

For many printing technologies each X-dimension is made up of a number of dots. When viewed under magnification, these dots (or pixels) can be measured. The example above shows four Data Matrix Cells each made up of 10x10 pixels.

Quiet Zone

Figure 3.6.2-6 Quiet Zones of a Data Matrix

A Quiet Zone with a minimum width of one module (X) is required all around the symbol as shown in the image above. If the Quiet Zone is less than one module (X) it will fail ISO/IEC

15415 verification. It can also be measured for diagnostic purposes.

The contrast is also a parameter of ISO/IEC 15415 verification, (see *3.5 Colours and contrast*)

3.6.2.2 AIM Quality Guidelines for Direct Part Marking (DPM)

AIM Global (the Association for Automatic Identification and Mobility) has acknowledged that ISO/IEC 15415 Print Quality Specifications are not sufficient for measuring the quality of Data Matrix symbols printed using Direct Part Marking (DPM) technologies. The AIM Global Technical Symbology Committee has developed AIM Global Document: AIM DPM -1-2006, Direct Part Mark (DPM), Quality Guideline for this purpose. The guideline is available at the AIM Global Website www.aimglobal.org.

Apart from the other parameters listed above, one of the key guidelines within the AIM document is
Modulation within a Cell:

Figure 3.6.2.2-1 Modulation within a Cell

As the name suggests, modulation within a cell requires uniformity of the reflectance of light and dark areas within one cell of the symbol. The example above highlights the type of printing problem that can lead to modulation within a cell.

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3.6.3 Possible causes of low grade

Parameter	Possible causes of low grades	Example
Symbol Contrast	Low background or light area reflectance, due to: • Poor choice of substrate (e.g., dark background) • Glossy laminate or overwrap High dark module reflectance, due to: • Unsuitable formulation or colour of ink • Insufficient ink coverage (e.g., non-overlapping dots) Inappropriate angle of illumination particularly for symbols printed using Direct Part Marking (DMP).	**Figure 3.6.3-1** Symbol Contrast
Decode	Many factors can cause the symbol to fail to decode. A major failure in any of the tested parameters or software errors in the printing system should be checked first.	
Unused Error Correction	Physical damage due to: • scuffing • tearing • deletions Bit errors due to print defects Excessive print growth Local deformation Misplaced modules	

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Parameter	Possible causes of low grades	Example
Modulation	Print growth or loss Verifier aperture set too large for X-dimension used Defects – print spots or voids (see defects) Irregular substrate reflectance Variation in ink coverage Show-through (often caused by printing on a transparent background) Transparency	**Figure 3.6.3-2** Print Growth **Figure 3.6.3-3** Print Loss
Fixed Pattern Damage	Spots of ink or other dark marks on the background Voids in printed areas Faulty print head elements or other print setup fault. Verifier aperture set too large for X-dimension used	**Figure 3.6.3-4** Fixed Pattern Damage
Axial Nonuniformity	Mismatch of transport speed in printing with symbol dimensions Printing software errors Verifier axis not perpendicular to symbol plane	X Y **Figure 3.6.3-5** Axial Nonuniformity
Grid Nonuniformity	Problems with the speed during printing (accelerations, decelerations, vibration, or slippage) Variable distance between the print head and the print surface Verifier axis not perpendicular to symbol plane	X Y **Figure 3.6.3-6** Grid Nonuniformity

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Parameter	Possible causes of low grades	Example
Print Growth/Loss	Largely dependent upon the exact print process used. Factors may include: • ink absorbency of the substrate • dot size (Inkjet and DPM) • incorrect thermal print head settings	

3.6.4 *The verification process*

The primary function of any bar code is carrying data from the point at which it is originated to the point at which the data has to be captured. Verification aims to check that the symbol is able to fulfill this function by ensuring compliance with the appropriate standard.

To be reliable, the verification process must be:

- Fully compliant and in accordance with standard ISO/IEC15426-2,
- Performed by a qualified operator.
- Cover both the print quality aspects (explained below) and the data content requirements explained by application guidelines. (See *2 Encoding data*)

For each of the parameters tested (see *3.6.1.2 Parameters measured and their significance*) the lowest achieved grade is taken and the Overall Symbol Grade is then an average of five individual tests. The verification should be performed under laboratory conditions using the required aperture, light and angle as described in ISO/IEC 15415.

During the verification testing, the intended area of application should be considered (for example, for healthcare applications a certain data content may be required (see A.8, Application Standard IFAH)

→ **Note:** It is important not to confuse **scanning** with **verification**. At best, scanning a symbol can be used as a "go/no-go" test of whether a symbol can be read by that scanner (only). Verification provides diagnostic information about any problem with a symbol and provides a high level of confidence that the symbol will scan in an open environment within its intended area of application. However, it should be noted that some symbols that fail verification will still be read by some bar code readers.

To control print quality during production, three main approaches can be taken:

1. Integrate bar code verification as part of the normal quality control procedure
2. Perform online scanning of all symbols to ensure readability
3. Perform sample scanning at periodic intervals during production

These three approaches are complementary and should be implemented according to overall quality requirements of the production line. However, there may be practical difficulties in scanning each of the printed symbols given the speed of some production lines and testing itself should also be used to ensure systems are maintained at the correct level by, for example, picking up a trend toward less high quality symbols.
Within the recommendations of the standards it is possible to check Print Quality online

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with:

- One check from a fixed position,
- Five successive checks from different positions within an arc of 72°. (as recommended in ISO/IEC 15415

The results should be recorded and reported in the same way as a for a general verification report (see *3.6.1.1 Print quality testing methodology*):

grade/aperture/light/angle

The size of the measuring aperture affects whether voids in the symbol will be "filled in" during the verification process. Therefore, the measuring aperture must be selected with reference to the range of nominal module size and expected scanning environment. An aperture that is too small will not fill in unintentional voids, or gaps between elements of the symbol that would lead to low grades or undecodable symbols. On the other hand, a measuring aperture that is too large will blur individual modules, resulting in low modulation, and may prevent the symbol from being decoded.

In general, the larger the aperture, the larger the acceptable size of spots and voids. Conversely, the smaller the aperture, the smaller the acceptable module size that can be read. Therefore, a successful application specification must select a measuring aperture that will predict the readability of both the largest and smallest module size symbols. The ideal theoretical size for the measuring aperture is between 40% and 80% of the maximum size of the X-dimension used in the symbol. However, as stated before, any application guideline will have to be taken into account. In order to demonstrate aperture, the aperture used to verify the symbol is represented by a yellow dot in the figure below.

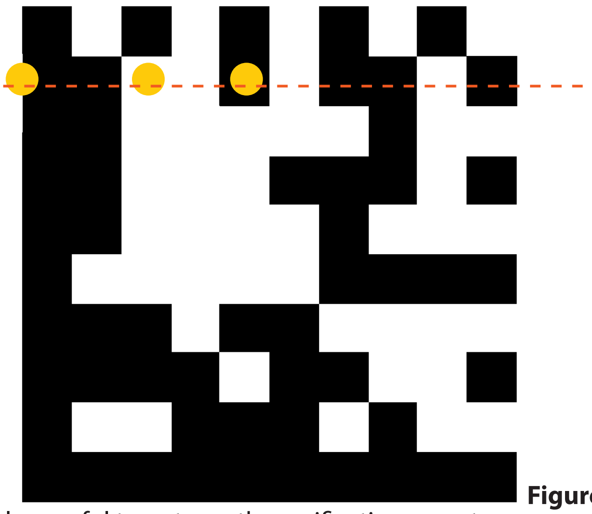

Figure 3.6.4-1 Aperture on a symbol

It also useful to note on the verification report :

- An indication of the verifier used (name and serial number)
- The date of the test and the name of the operator who performed it
- Comments on the substrate and, if possible, the print process used (in case either is changed at some point in the future, thus invalidating the test report)

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3.6.5 Selecting a verifier

GS1 is often asked for advice on the selection of equipment. There are a number of providers who make excellent verification equipment available on the market, GS1, however, is commercially impartial and as such cannot favour any vendor. But the following may be helpful when selecting a verifier.

Firstly, compliance with the appropriate standard should be considered a pre-requisite. The three standards ISO/IEC15426-2, ISO/IEC15415 and ISO/IEC 16022 should be supported by the verifier.

Secondly, the verifier must be capable of consistent performance (e.g., the same symbol will yield the same result when tested). Initially, this is achieved by the factory set-up of the verifier. However, to maintain this consistency the verifier should be calibrated using a GS1 Calibration Conformance Test Card in line with the manufacturer's instructions.

Other features that should be considered, include:

- The pixel size of the camera used should be suitable for the size of the Data Matrix symbols being tested
- What wavelength light source does it use? The GS1 General Specifications require 670 nm ± 10 nm.
- What measuring aperture(s) is/are available.
- What form of output is available (e.g., LEDs, display, printout of details, PC connection, etc.)?
- Can it perform scan averaging (to meet the 5 scan requirement)?
- Fuzzy logic should be avoided in verifiers. While some aggressive scanners use fuzzy logic to try and read poor quality bar codes, such features should be avoided in verification equipment whose goal is to help improve bar code quality.
- The manufacturer's control / re-calibration requirements.

Independent of the verification equipment used, extensive studies have shown that operators of verifiers require proper training. Additionally, in order to achieve consistent results, verifiers require regular calibration by using the GS1 Calibrated Conformance Test Card for GS1 DataMatrix, in accordance with manufacturer recommendations.

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3.7 Recommendations when developing Application Standards

Any Application Standard for GS1 DataMatrix must set the clear, achievable and independently measurable print quality requirements. Users of the Application Standard are likely to make their choice of printing technology based upon the Print Quality requirements stated.

In terms of Print Quality an Application Standard must, at minimum, specify:

- The methodology for measuring the Print Quality. For GS1 ISO/IEC 15415 is considered the de-facto methodology
- A minimum acceptable Print Quality Grade as per the methodology used. For example, grade 1.5 according to ISO/IEC 15415
- Depending upon the exact Application Standards, it may include:
  - Symbol location guidelines
  - Minimum and Maximum X-dimensions
  - The print process used to create the symbol (e.g., printed labels may create a perfect symbol but will not be suitable for products that require heat-sterilisation)

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4 Reading and decoding Data Matrix

Once the symbol is printed, a reading or scanning device is required to capture the encoded data. The word 'scanning' is normally used to cover two separate process steps:

1. The actual scan (the reading of the dark and light areas)
2. The decode (the processing of the captured image to determine the encoded data)

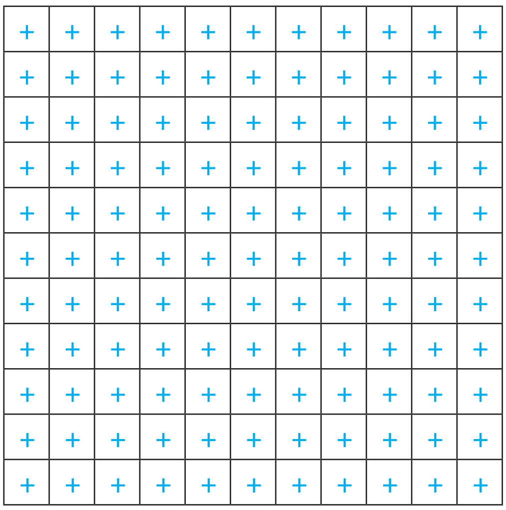
In this regard Data Matrix ECC 200 performs very similar to the well known linear bar codes endorsed by GS1, such as EAN-13, ITF-14, GS1-128 and GS1 DataBar. However, it differs from these linear symbols by requiring a camera or imaging based scan as data is encoded in two-dimensions.

Once decoded, the data will be passed to an information system for further processing.

4.1 Principles of reading Data Matrix

Like other 2D bar codes, Data Matrix can only be read by imaging cameras or CCD (Charge Couple Device) devices. The principle is based upon first capturing the image of the symbol and then analyzing it. The finder patterns (see *1.1 General_structure*) are used to recreate a virtual image of the matrix.

Typically, each of the dark and light areas within the matrix are converted to binary values (1 or 0). This is then processed according the reference decode algorithm of Data Matrix as defined in ISO/IEC 16022 based upon an ideal image



+ = Ideal Centre of each module

Figure 4.1-1 Ideal Grid

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4.2 Scanners for GS1 DataMatrix

4.2.1 Introduction

Data Matrix symbols require scanners that can read in 2-dimensions. Typically this requires camera or imaging technology. This is a different technology from the one used by many of the laser scanners for reading linear bar code symbols. A linear symbol, like EAN-13 or GS1-128 can be read by a single laser beam passing across the length of the symbol. However, to read Data Matrix symbol requires the entire image to be read in both the X and Y axis.

Camera based scanning systems tend to have the ability to distinguish up to 256 levels of grayscale. This advantage enables some specific camera based scanning systems to better handle very low contrast symbols such as those directly engraved in the metal (see *3.5 Colours and contrast*).

It is important to note that almost any scanner capable of reading GS1 DataMatrix can also read linear bar codes as well (GS1-128, EAN-13, UPC-A, etc.).

4.2.2 Selecting a scanner

GS1 is often asked for advice on the selection of equipment. There are a number of providers who make excellent scanning equipment available on the market, GS1, however, is commercially impartial and as such cannot favor any vendor. Like in any commercial market, different products have different strengths and weaknesses. The exact choice of scanner will depend on many factors including price, operating environment, etc. There are, however, two factors which are likely to impact quality:

1. Software for image processing and decoding,
2. The optics and sensors

4.2.2.1 Image processing and decoding

The exact internal workings of a scanning and the decoding system used in a particular scanner are normally commercially sensitive information .Companies only publish the capabilities of a scanner . However, in broad terms, the decoding software must be in line with the reference decode algorithm.

The quality of the image captured will be determined, in part, by the resolution of the device and some manufacturers use 'aggressive' processing algorithms, using fuzzy logic, to try and read distorted images or damaged symbols. It is important to note high quality symbols are required not just to ensure good read rates with any scanner but also to protect against mis-reads from over-aggressive scanners.

4.2.2.2 The ability to program the scanner

Many modern scanners can be fairly simply programed to enable or disable features. The manufacturer guide will often allow the scanner to adjust characteristics such as:

- the symbologies that need to be read
- The communication protocol (e.g., using symbology identifiers)

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- Reading of reverse / inverse reflectance ("black on white" or "white on black") images

Manufacturers may also provide features to deal with the non-printable characters, for example the Group Separator, which is essential for decoding messages containing variable length data.

4.2.2.3 Optics and sensors

As in the case of digital cameras, the image quality obtained depends on several factors. While important, the number of pixels is not the only factor. Indeed the sensor will have an ability to deal with a certain number of pixels and, in very broad terms, the larger the number of pixels the better the definition of the image will be. The scanner will also make use of lenses. The focal length is not provided and some will be better at reading from a distance and others at reading close up. In very broad terms, reading very small bar codes is best done with scanner with a short focal distance, reading larger codes with a larger focal distance.
The depth of field is also an important factor. Manufacturers often show the various reading distances that the device can achieve based upon the X-dimension used.

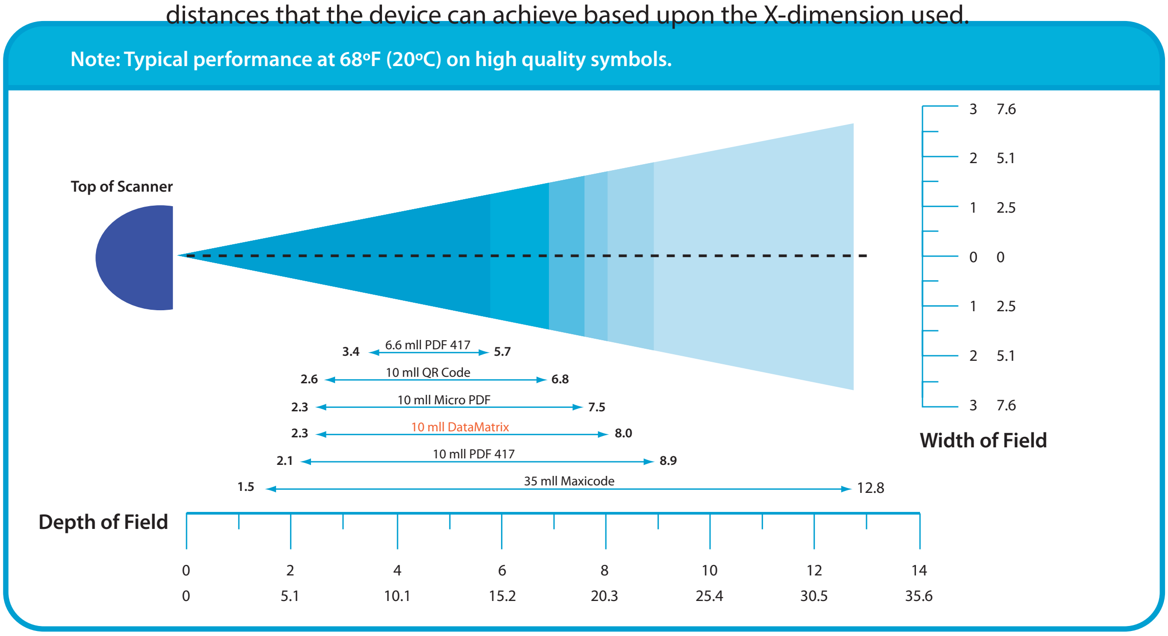

Figure 4.2.2.3-1 Typical Reading distance and the depth of a scanner

The figure above is an example of typical reading capabilities of a scanner. showing the reading distance and the depth of field. However, critical factors also include the type of symbol, the exact X-dimension and the print quality of the symbol.

Where the scanner is in a fixed position, it should of course be positioned at a suitable distance from the products it has to read. For hand-held scanners, the operator can easily adjust the scanning distance to obtain a scan.

4.3 Decoding

As highlighted above (see *Principles of reading Data Matrix*), scanning is in fact a two-step process. Decoding takes the scanned image and decodes the encoded data.

4.3.1 The principles of decoding

The scanner can be programmed to recognise a GS1 DataMatrix symbol, thanks to its decoding system and the unique patterns (the Data Matrix finder patterns and the leading FNC1). This is a key security feature allowing the scanner to distinguish between data encoded according to the GS1 Application Identifiers rules and any other data. This offers system protection and allows GS1 Application Identifiers to be correctly interpreted.

Ideally the scanner then passes the decoded data using the Symbology Identifier (]**d2**) to the processing system. Depending on where within the data an FNC 1 is found there are by ISO/IEC definition different Symbology Identifiers that are output. For the GS1 System only FNC1 in the first position is supported and results in the necessary (]**d2**) as the Symbology Identifier output by the scanner. This Symbol Identifier indicates that the decoded data came from a GS1 DataMatrix symbol and can therefore be processed according to the GS1 Application Identifier rules.

]d2 is a system feature and is never directly encoded into the GS1 DataMatrix symbol

4.3.2 Transmission of data strings

The scanner does not normally contain any intelligence but simply transfers the string of characters read from the symbol to the Information System for further processing.
The leading FNC1 in GS1 DataMatrix is interpreted as the symbology identifier "]d2". A typical example is below:

Figure 4.3.2-1 Symbology Identifier Example

the data encoded is FNC101034531200000111708050810ABCD1234
FNC14109501101020917

The data transmitted to the application software for the first FNC1 (See *Function 1 Symbol Character (FNC1)*), is the symbology identifier]d2 and for the second FNC1, when used as a separator character is <GS> Group-Separator. The above example would result in:

]d202034531200000111709112510ABCD1234<GS>3710

This string of data is then passed to the processing system or, in some more sophisticated scanner/decoder devices, the string of data is already interpreted according the GS1 Application Identifier rules (see *Pre-defined length vs fixed length GS1 Application Identifiers*)

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0203453120000011 ; 17091125 ; 10ABCD1234 ; 3710

In other systems the data string may be transmitted in ASCII characters:

```
0000  5d 64 32 30 32 30 33 34  35 33 31 32 30 30 30 30  |]d20203453120000|
0010  30 31 31 31 37 30 39 31  31 32 35 31 30 41 42 43  |0111709112510ABC|
0020  44 31 32 33 34 1d 33 37  31 30 0d 0a              |D1234~3710~~    |
```

Or even in hexadecimal:
5D6432303230333435333132303030303031313137303931313235313041424344313233341D333731300D0A

Please note that, field separator <GS> is transmitted as a “~” character in the first example above.

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Annexes

A.1 Full list of GS1 Application Identifiers in numerical order

The table below lists all the GS1 Application Identifiers (AIs). For full definitions, please see the GS1 General Specifications.

AI	Data Content	Format*
00	SSCC (Serial Shipping Container Code)	n2+n18
01	Global Trade Item Number (GTIN)	n2+n14
02	GTIN of Contained Trade Items	n2+n14
10	Batch or Lot Number	n2+X..20
11 (**)	Production Date (YYMMDD)	n2+n6
12 (**)	Due Date (YYMMDD)	n2+n6
13 (**)	Packaging Date (YYMMDD)	n2+n6
15 (**)	Best Before Date (YYMMDD)	n2+n6
16 (**)	Sell By Date (YYMMDD)	n2+n6
17 (**)	Expiration Date (YYMMDD)	n2+n6
20	Variant Number	n2+n2
21	Serial Number	n2+X..20
240	Additional Item Identification	n3+X..30
241	Customer Part Number	n3+X..30
242	Made-to-Order Variation Number	n2+n…6
243	Packaging Component Number	n3+X..20
250	Secondary Serial Number	n3+X..30
251	Reference to Source Entity	n3+X..30
253	Global Document Type Identifier (GDTI)	n3+n13+n..17
254	GLN Extension Component	n3+X..20
255	Global Coupon Number (GCN)	n3+n13+n..12
30	Count of Items (Variable Measure Trade Item)	n2+n..8
310 (***)	Net weight, kilograms (Variable Measure Trade Item)	n4+n6
311 (***)	Length of first dimension, metres (Variable Measure Trade Item)	n4+n6
312 (***)	Width, diametre, or second dimension, metres (Variable Measure Trade Item)	n4+n6
313 (***)	Depth, thickness, height, or third dimension, metres (Variable Measure Trade Item)	n4+n6
314 (***)	Area, square metres (Variable Measure Trade Item)	n4+n6
315 (***)	Net volume, litres (Variable Measure Trade Item)	n4+n6

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AI	Data Content	Format*
316 (***)	Net volume, cubic metres (Variable Measure Trade Item)	n4+n6
320 (***)	Net weight, pounds (Variable Measure Trade Item)	n4+n6
321 (***)	Length or first dimension, inches (Variable Measure Trade Item)	n4+n6
322 (***)	Length or first dimension, feet (Variable Measure Trade Item)	n4+n6
323 (***)	Length or first dimension, yards (Variable Measure Trade Item)	n4+n6
324 (***)	Width, diametre, or second dimension, inches (Variable Measure Trade Item)	n4+n6
325 (***)	Width, diametre, or second dimension, feet (Variable Measure Trade Item)	n4+n6
326 (***)	Width, diametre, or second dimension, yards (Variable Measure Trade Item	n4+n6
327 (***)	Depth, thickness, height, or third dimension, inches (Variable Measure Trade Item)	n4+n6
328 (***)	Depth, thickness, height, or third dimension, feet (Variable Measure Trade Item)	n4+n6
329 (***)	Depth, thickness, height, or third dimension, yards (Variable Measure Trade Item)	n4+n6
330 (***)	Logistic weight, kilograms	n4+n6
331 (***)	Length or first dimension, metres	n4+n6
332 (***)	Width, diametre, or second dimension, metres	n4+n6
333 (***)	Depth, thickness, height, or third dimension, metres	n4+n6
334 (***)	Area, square metres	n4+n6
335 (***)	Logistic volume, litres	n4+n6
336 (***)	Logistic volume, cubic litres	n4+n6
337 (***)	Kilograms per square metre	n4+n6
340 (***)	Logistic weight, pounds	n4+n6
341 (***)	Length or first dimension, inches	n4+n6
342 (***)	Length or first dimension, feet	n4+n6
343 (***)	Length or first dimension, yards	n4+n6
344 (***)	Width, diametre, or second dimension	n4+n6
345 (***)	Width, diametre, or second dimension	n4+n6
346 (***)	Width, diametre, or second dimension	n4+n6
347 (***)	Depth, thickness, height, or third dimension	n4+n6
348 (***)	Depth, thickness, height, or third dimension	n4+n6
349 (***)	Depth, thickness, height, or third dimension	n4+n6
350 (***)	Area, square inches (Variable Measure Trade Item)	n4+n6
351 (***)	Area, square feet (Variable Measure Trade Item)	n4+n6

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AI	Data Content	Format*
352 (***)	Area, square yards (Variable Measure Trade Item)	n4+n6
353 (***)	Area, square inches	n4+n6
354 (***)	Area, square feet	n4+n6
355 (***)	Area, square yards	n4+n6
356 (***)	Net weight, troy ounces (Variable Measure Trade Item)	n4+n6
357 (***)	Net weight (or volume), ounces (Variable Measure Trade Item)	n4+n6
360 (***)	Net volume, quarts (Variable Measure Trade Item)	n4+n6
361 (***)	Net volume, gallons U.S. (Variable Measure Trade Item)	n4+n6
362 (***)	Logistic volume, quarts	n4+n6
363 (***)	Logistic volume, gallons U.S.	n4+n6
364 (***)	Net volume, cubic inches (Variable Measure Trade Item)	n4+n6
365 (***)	Net volume, cubic feet (Variable Measure Trade Item)	n4+n6
366 (***)	Net volume, cubic yards (Variable Measure Trade Item)	n4+n6
367 (***)	Logistic volume, cubic inches	n4+n6
368 (***)	Logistic volume, cubic feet	n4+n6
369 (***)	Logistic volume, cubic yards	n4+n6
37	Count of Trade Items	n2+n..8
390 (***)	Applicable Amount Payable, local currency	n4+n..15
391 (***)	Applicable Amount Payable with ISO Currency Code	n4+n3+n..15
392 (***)	Applicable Amount Payable, single monetary area (Variable Measure Trade Item)	n4+n..15
393 (***)	Applicable Amount Payable with ISO Currency Code (Variable Measure Trade Item)	n4+n3+n..15
400	Customer's Purchase Order Number	n3+x..30
401	Global Identification Number for Consignment (GINC)	n3+x..30
402	Global Shipment Identification Number (GSIN)	n3+n17
403	Routing Code	n3+x..30
410	Ship to - Deliver to Global Location Number	n3+n13
411	Bill to - Invoice to Global Location Number	n3+n13
412	Purchased from Global Location Number	n3+n13
413	Ship for - Deliver for - Forward to Global Location Number	n3+n13
414	Identification of a Physical Location - Global Location Number	n3+n13
415	Global Location Number of the Invoicing Party	n3+n13
420	Ship to - Deliver to Postal Code Within a Single Postal Authority	n3+X..20
421	Ship to - Deliver to Postal Code with ISO Country Code	n3+n3+X..9
422	Country of Origin of a Trade Item	n3+n3

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AI	Data Content	Format*
423	Country of Initial Processing	n3+n3+n..12
424	Country of Processing	n3+n3
425	Country of Disassembly	n3+n3
426	Country Covering full Process Chain	n3+n3
427	Country Subdivision of Origin	n3+X..3
7001	NATO Stock Number (NSN)	n4+n13
7002	UN/ECE Meat Carcasses and Cuts Classification	n4+X..30
7003	Expiration Date and Time	n4+n10
7004	Active Potency	n4+n..4
703s	Approval Number of Processor with ISO Country Code	n4+n3+X..27
710	National Healthcare Reimbursement Number (NHRN) - Germany PZN	n3+X..20
711	National Healthcare Reimbursement Number (NHRN) - France CIP	n3+X..20
712	National Healthcare Reimbursement Number (NHRN) - Spain CN	n3+X..20
713	National Healthcare Reimbursement Number (NHRN) - Brasil DRN	n3+X..20
nnn*	National Healthcare Reimbursement Number(NHRN) - Country "A" NHRN	n4+n14
8001	Roll Products (Width, Length, Core Diametre, Direction, Splices)	n4+n14
8002	Cellular Mobile Telephone Identifier	n4+X..20
8003	Global Returnable Asset Identifier (GRAI)	n4+n14+X..16
8004	Global Individual Asset Identifier (GIAI)	n4+X..30
8005	Price Per Unit of Measure	n4+n6
8006	Identification of the Components of a Trade Item	n4+n14+n2+n2
8007	International Bank Account Number (IBAN)	n4+X..30
8008	Date and Time of Production	n4+n8+n..4
8010	Component/Part Identifier (CPID)	n4+X..30
8011	Component / Part Identifier Serial Number (CPID SERIAL)	n4+n..12
8017	Global Service Relation Number to identify the relationship between an organisation offering services and the provider of services	n4+n18
8018	Global Service Relation Number to identify the relationship between an organisation offering services and the recipient of services	n4+n18
8019	Service Relation Instance Number (SRIN)	n4+n18
8020	Payment Slip Reference Number	n4+X..25
8100	GS1-128 Coupon Extended Code	n4+n6
8101	GS1-128 Coupon Extended Code	n4+n1+n5+n4

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AI	Data Content	Format*
8102	GS1-128 Coupon Extended Code	n4+n1+n1
8110	Coupon Code Identification for Use in North America	n4+an..30
8200	Extended Packaging URL	n4+X..70
90	Information Mutually Agreed Between Trading Partners	n2+X..30
91 to 99	Company Internal Information	n2+X..30

Notes:

(*) The first position indicates the length (number of digits) of the GS1 Application Identifier. The following value refers to the format of the data content.
(**) If only year and month are available, DD must be filled with two zeroes.
(***) The fourth digit of this GS1 Application Identifier indicates the implied decimal point position.

Example:

- 3100 Net weight in kg without a decimal point
- 3102 Net weight in kg with two decimal points

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A.2 GS1 size recommendations for symbols using Data Matrix

GS1 System Symbol Specification Table 7 - Direct Part Marking (Figure 5.5.2.7 - 8 of the GS1 General Specifications (version 14)) Please refer to GS1 General Specifications for full view of tables.

Symbol(s) Specified	X-Dimension mm (inches) (Note 1 Note 6)			Minimum Symbol Height for Given X mm (inches)			* Quiet Zone	Minimum Quality Specifica-tion	
	Minimum	Target	Maximum	Minimum	Target	Maximum	All Four Sides		
GS1 DataMatrix	0.255 (0.0100”)	0.3 (0.0118”)	0.615 (0.0242”)	Height is determined by X-Dimension for data that is encoded			1X on all four sides	1.5/06/670 Note 5	For Direct Marking of items other than Small Medical/Surgical Instruments
GS1 DataMatrix Ink Based Direct Part Marking	0.255 (0.0100”)	0.3 (0.0118”)	0.615 (0.0242”	Height is determined by X-Dimension for data that is encoded			1X on all four sides	1.5/08/670 Note 5	For Small Medical/ Surgical Instruments Direct Marking
GS1 DataMatrix Ink Based Direct Part Marking - A Note 2	0.100 (0.0039”)	0.200 (0.0079”)	0.300 (0.0118”	Height is determined by X-Dimension for data that is encoded			1X on all four sides	1.5/03/ Note 3 Note 4 Note 5	For Small Medical/ Surgical Instruments Direct Marking
GS1 DataMatrix Ink Based Direct Part Marking - B Note 2	0.200 (0.0079”)	0.300 (0.0118”)	0.495 (0.0195”)	Height is determined by X-Dimension for data that is encoded			1X on all four sides	1.5/06/ Note 3 Note 4 Note 5	For Small Medical/ Surgical Instruments Direct Marking

Note 1: Optical effects in the image capture process require that label based GS1 DataMatrix symbols be printed at approximately 1.5 times the equivalent X-dimensionallowed for linear symbols in the same application.

Note 2: There are two basic types of non ink based Direct Part Marks, those with “connected modules” in the “L” shaped finder pattern (GS1 DataMatrix Direct Part Marking – A) created by DPM marking technologies such as laser or chemical etching and those with “non connected modules” in the “L” shaped finder pattern (GS1 DataMatrix Direct Part Marking – B) created by DPM marking technologies such as dot peen. Due to the marking technologies and characteristics of reading they each have varied ranges of X-Dimensions and different quality criteria recommended and may require different reading equipment. GS1 DataMatrix – A is suggested for marking of small medical / surgical instruments. The Minimum X-Dimension of 0.100mm is based upon the specific need for permanence in direct marking of small medical instruments which have limited marking area available on the instrument with a target useable area of 2.5mm x 2.5mm and a data content of GTIN (AI 01) plus Serial Number (AI 21).

Note 3: The wavelength for Direct Part Marked GS1 DataMatrix is based upon the practical scanning environment and thus must in the grade be matched to the scanner / imagers being used. See ISO/IEC 15415 and AIM DPM-1-2006.

Note 4: The angle is an additional parameter defining the angle of incidence (relative to the plane of the symbol) of the illumination for Direct Part Marking verification. It shall be included in the overall symbol grade when the angle of incidence is other than 45 degrees. Its absence indicates that the angle of incidence is 45 degrees. See ISO/IEC 15415 and AIM DPM-1-2006.

Note 5: The effective aperture for GS1 DataMatrix quality measurements should be taken at 80 percent of the minimum X-dimension allowed for the application. For Direct Part Marking - A this would equate to an aperture of 3; for Direct Park Marking – B this would equate to an aperture of 6 and for general healthcare label printing, an aperture of 8. See ISO/IEC 15415 and AIM DPM-1-2006.

Note 6: The largest X-dimension in a given range that will allow a symbol with the needed data content to fit within the available marking area should be used to maximize marking and reading performance (depth of field, tolerance to curvature, etc.).

Note: In small instrument marking, mixed marking technologies used within the same scanning environment should be avoided to ensure highest reading performance. Laser etching is recommended for small instrument marking.

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A.3 The International Standard ISO/IEC 646 for representation of each character

Graphic Symbol	Name	Coded Representation	Graphic Symbol	Name	Coded Representation
!	Exclamation mark	2/1	M	Capital letter M	4/13
"	Quotation mark	2/2	N	Capital letter N	4/14
%	Percent sign	2/5	O	Capital letter O	4/15
&	Ampersand	2/6	P	Capital letter P	5/0
'	Apostrophe	2/7	Q	Capital letter Q	5/1
(	Left parenthesis	2/8	R	Capital letter R	5/2
)	Right parenthesis	2/9	S	Capital letter S	5/3
*	Asterisk	2/10	T	Capital letter T	5/4
+	Plus sign	2/11	U	Capital letter U	5/5
,	Comma	2/12	V	Capital letter V	5/6
-	Hyphen/Minus	2/13	W	Capital letter W	5/7
.	Full stop	2/14	X	Capital letter X	5/8
/	Solidus	2/15	Y	Capital letter Y	5/9
0	Digit zero	3/0	Z	Capital letter Z	5/10
1	Digit one	3/1	_	Low line	5/15
2	Digit two	3/2	a	Small letter a	6/1
3	Digit three	3/3	b	Small letter b	6/2
4	Digit four	3/4	c	Small letter c	6/3
5	Digit five	3/5	d	Small letter d	6/4
6	Digit six	3/6	e	Small letter e	6/5
7	Digit seven	3/7	f	Small letter f	6/6
8	Digit eight	3/8	g	Small letter g	6/7
9	Digit nine	3/9	h	Small letter h	6/8
:	Colon	3/10	i	Small letter i	6/9
;	Semicolon	3/11	j	Small letter j	6/10
<	Less-than sign	3/12	k	Small letter k	6/11
=	Equals sign	3/13	l	Small letter l	6/12
>	Greater-than sign	3/14	m	Small letter m	6/13
?	Question mark	3/15	n	Small letter n	6/14
A	Capital letter A	4/1	o	Small letter o	6/15
B	Capital letter B	4/2	p	Small letter p	7/0
C	Capital letter C	4/3	q	Small letter q	7/1
D	Capital letter D	4/4	r	Small letter r	7/2
E	Capital letter E	4/5	s	Small letter s	7/3
F	Capital letter F	4/6	t	Small letter t	7/4
G	Capital letter G	4/7	u	Small letter u	7/5
H	Capital letter H	4/8	v	Small letter v	7/6
I	Capital letter I	4/9	w	Small letter w	7/7

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A.4 The International Standard ISO/IEC 646 for representation of each character

Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	00	Null	32	20	Space	64	40	@	96	60	`
1	01	Start of heading	33	21	!	65	41	A	97	61	a
2	02	Start of text	34	22	"	66	42	B	98	62	b
3	03	End of text	35	23	#	67	43	C	99	63	c
4	04	End of transmit	36	24	$	68	44	D	100	64	d
5	05	Enquiry	37	25	%	69	45	E	101	65	e
6	06	Acknowledge	38	26	&	70	46	F	102	66	f
7	07	Audible bell	39	27	'	71	47	G	103	67	g
8	08	Backspace	40	28	(	72	48	H	104	68	h
9	09	Horizontal tab	41	29	)	73	49	I	105	69	i
10	0A	Line feed	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage return	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	47	2F	/	79	4F	O	111	6F	o
16	10	Data link escape	48	30	0	80	50	P	112	70	p
17	11	Device control 1	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	50	32	2	82	52	R	114	72	r
19	13	Device control 3	51	33	3	83	53	S	115	73	s
20	14	Device control 4	52	34	4	84	54	T	116	74	t
21	15	Neg. acknowledge	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	54	36	6	86	56	V	118	76	v
23	17	End trans. block	55	37	7	87	57	W	119	77	w
24	18	Cancel	56	38	8	88	58	X	120	78	x
25	19	End of medium	57	39	9	89	59	Y	121	79	y
26	1A	Substitution	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	63	3F	?	95	5F	_	127	7F	□

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Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
128	80	Ç	160	A0	á	192	C0	└	224	E0	α
129	81	ü	161	A1	í	193	C1	┴	225	E1	ß
130	82	é	162	A2	ó	194	C2	┬	226	E2	Γ
131	83	â	163	A3	ú	195	C3	├	227	E3	π
132	84	ä	164	A4	ñ	196	C4	─	228	E4	Σ
133	85	à	165	A5	Ñ	197	C5	┼	229	E5	σ
134	86	å	166	A6	ª	198	C6	╞	230	E6	µ
135	87	ç	167	A7	º	199	C7	╟	231	E7	τ
136	88	ê	168	A8	¿	200	C8	╚	232	E8	Φ
137	89	ë	169	A9	⌐	201	C9	╔	233	E9	Θ
138	8A	è	170	AA	¬	202	CA	╩	234	EA	Ω
139	8B	ï	171	AB	½	203	CB	╦	235	EB	δ
140	8C	î	172	AC	¼	204	CC	╠	236	EC	∞
141	8D	ì	173	AD	¡	205	CD	═	237	ED	φ
142	8E	Ä	174	AE	«	206	CE	╬	238	EE	ε
143	8F	Å	175	AF	»	207	CF	╧	239	EF	∩
144	90	É	176	B0	░	208	D0	╨	240	F0	≡
145	91	æ	177	B1	▒	209	D1	╤	241	F1	±
146	92	Æ	178	B2	▓	210	D2	╥	242	F2	≥
147	93	ô	179	B3	│	211	D3	╙	243	F3	≤
148	94	ö	180	B4	┤	212	D4	╘	244	F4	⌠
149	95	ò	181	B5	╡	213	D5	╒	245	F5	⌡
150	96	û	182	B6	╢	214	D6	╓	246	F6	÷
151	97	ù	183	B7	╖	215	D7	╫	247	F7	≈
152	98	ÿ	184	B8	╕	216	D8	╪	248	F8	°
153	99	Ö	185	B9	╣	217	D9	┘	249	F9	∙
154	9A	Ü	186	BA	║	218	DA	┌	250	FA	·
155	9B	¢	187	BB	╗	219	DB	█	251	FB	√
156	9C	£	188	BC	╝	220	DC	▄	252	FC	ⁿ
157	9D	¥	189	BD	╜	221	DD	▌	253	FD	²
158	9E	₧	190	BE	╛	222	DE	▐	254	FE	■
159	9F	ƒ	191	BF	┐	223	DF	▀	255	FF	□

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Binary representation

Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary
0	0	000	00000000	16	10	020	00010000	32	20	040	00100000	48	30	060	00110000
1	1	001	00000001	17	11	021	00010001	33	21	041	00100001	49	31	061	00110001
2	2	002	00000010	18	12	022	00010010	34	22	042	00100010	50	32	062	00110010
3	3	003	00000011	19	13	023	00010011	35	23	043	00100011	51	33	063	00110011
4	4	004	00000100	20	14	024	00010100	36	24	044	00100100	52	34	064	00110100
5	5	005	00000101	21	15	025	00010101	37	25	045	00100101	53	35	065	00110101
6	6	006	00000110	22	16	026	00010110	38	26	046	00100110	54	36	066	00110110
7	7	007	00000111	23	17	027	00010111	39	27	047	00100111	55	37	067	00110111
8	8	010	00001000	24	18	030	00011000	40	28	050	00101000	56	38	070	00111000
9	9	011	00001001	25	19	031	00011001	41	29	051	00101001	57	39	071	00111001
10	A	012	00001010	26	1A	032	00011010	42	2A	052	00101010	58	3A	072	00111010
11	B	013	00001011	27	1B	033	00011011	43	2B	053	00101011	59	3B	073	00111011
12	C	014	00001100	28	1C	034	00011100	44	2C	054	00101100	60	3C	074	00111100
13	D	015	00001101	29	1D	035	00011101	45	2D	055	00101101	61	3D	075	00111101
14	E	016	00001110	30	1E	036	00011110	46	2E	056	00101110	62	3E	076	00111110
15	F	017	00001111	31	1F	037	00011111	47	2F	057	00101111	63	3F	077	00111111

Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary
64	40	100	01000000	80	50	120	01010000	96	60	140	01100000	112	70	160	01110000
65	41	101	01000001	81	51	121	01010001	97	61	141	01100001	113	71	161	01110001
66	42	102	01000010	82	52	122	01010010	98	62	142	01100010	114	72	162	01110010
67	43	103	01000011	83	53	123	01010011	99	63	143	01100011	115	73	163	01110011
68	44	104	01000100	84	54	124	01010100	100	64	144	01100100	116	74	164	01110100
69	45	105	01000101	85	55	125	01010101	101	65	145	01100101	117	75	165	01110101
70	46	106	01000110	86	56	126	01010110	102	66	146	01100110	118	76	166	01110110
71	47	107	01000111	87	57	127	01010111	103	67	147	01100111	119	77	167	01110111
72	48	110	01001000	88	58	130	01011000	104	68	150	01101000	120	78	170	01111000
73	49	111	01001001	89	59	131	01011001	105	69	151	01101001	121	79	171	01111001
74	4A	112	01001010	90	5A	132	01011010	106	6A	152	01101010	122	7A	172	01111010
75	4B	113	01001011	91	5B	133	01011011	107	6B	153	01101011	123	7B	173	01111011
76	4C	114	01001100	92	5C	134	01011100	108	6C	154	01101100	124	7C	174	01111100
77	4D	115	01001101	93	5D	135	01011101	109	6D	155	01101101	125	7D	175	01111101
78	4E	116	01001110	94	5E	136	01011110	110	6E	156	01101110	126	7E	176	01111110
79	4F	117	01001111	95	5F	137	01011111	111	6F	157	01101111	127	7F	177	01111111

Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary
128	80	200	10000000	144	90	220	10010000	160	A0	240	10100000	176	B0	260	10110000
129	81	201	10000001	145	91	221	10010001	161	A1	241	10100001	177	B1	261	10110001
130	82	202	10000010	146	92	222	10010010	162	A2	242	10100010	178	B2	262	10110010
131	83	203	10000011	147	93	223	10010011	163	A3	243	10100011	179	B3	263	10110011
132	84	204	10000100	148	94	224	10010100	164	A4	244	10100100	180	B4	264	10110100
133	85	205	10000101	149	95	225	10010101	165	A5	245	10100101	181	B5	265	10110101
134	86	206	10000110	150	96	226	10010110	166	A6	246	10100110	182	B6	266	10110110
135	87	207	10000111	151	97	227	10010111	167	A7	247	10100111	183	B7	267	10110111
136	88	210	10001000	152	98	230	10011000	168	A8	250	10101000	184	B8	270	10111000
137	89	211	10001001	153	99	231	10011001	169	A9	251	10101001	185	B9	271	10111001
138	8A	212	10001010	154	9A	232	10011010	170	AA	252	10101010	186	BA	272	10111010
139	8B	213	10001011	155	9B	233	10011011	171	AB	253	10101011	187	BB	273	10111011
140	8C	214	10001100	156	9C	234	10011100	172	AC	254	10101100	188	BC	274	10111100
141	8D	215	10001101	157	9D	235	10011101	173	AD	255	10101101	189	BD	275	10111101
142	8E	216	10001110	158	9E	236	10011110	174	AE	256	10101110	190	BE	276	10111110
143	8F	217	10001111	159	9F	237	10011111	175	AF	257	10101111	191	BF	277	10111111

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Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary	Dec	Hex	Oct	Binary
192	C0	300	11000000	208	D0	320	11010000	224	E0	340	11100000	240	F0	360	11110000
193	C1	301	11000001	209	D1	321	11010001	225	E1	341	11100001	241	F1	361	11110001
194	C2	302	11000010	210	D2	322	11010010	226	E2	342	11100010	242	F2	362	11110010
195	C3	303	11000011	211	D3	323	11010011	227	E3	343	11100011	243	F3	363	11110011
196	C4	304	11000100	212	D4	324	11010100	228	E4	344	11100100	244	F4	364	11110100
197	C5	305	11000101	213	D5	325	11010101	229	E5	345	11100101	245	F5	365	11110101
198	C6	306	11000110	214	D6	326	11010110	230	E6	346	11100110	246	F6	366	11110110
199	C7	307	11000111	215	D7	327	11010111	231	E7	347	11100111	247	F7	367	11110111
200	C8	310	11001000	216	D8	330	11011000	232	E8	350	11101000	248	F8	370	11111000
201	C9	311	11001001	217	D9	331	11011001	233	E9	351	11101001	249	F9	371	11111001
202	CA	312	11001010	218	DA	332	11011010	234	EA	352	11101010	250	FA	372	11111010
203	CB	313	11001011	219	DB	333	11011011	235	EB	353	11101011	251	FB	373	11111011
204	CC	314	11001100	220	DC	334	11011100	236	EC	354	11101100	252	FC	374	11111100
205	CD	315	11001101	221	DD	335	11011101	237	ED	355	11101101	253	FD	375	11111101
206	CE	316	11001110	222	DE	336	11011110	238	EE	356	11101110	254	FE	376	11111110
207	CF	317	11001111	223	DF	337	11011111	239	EF	357	11101111	255	FF	377	11111111

Worked example of conversion for decimal to binary:
204 (decimal) = $1x2^7+1x2^6+0x2^5+0x2^4+1x2^3+1x2^2+0x2^1+0x2^0$

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A.5 Protocol used to encode ASCII in Data Matrix ECC 200

Extracted from the standard ISO/IEC 16022

Table 2 - ASCII encodation values

Codeword	Data or function
1-128	ASCII data (ASCII value + 1)
129	Pad
130-229	2-digit data 00-99 (Numeric Value + 130)
230	Latch to C40 encodation
231	Latch to Base 256 encodation
232	FNC1
233	Structured Append
234	Reader Programming
235	Upper Shrit (shift to Extended ASCII)
236	05 Macro
237	06 Macro
238	Latch to ANSI X12 encodation
239	Latch to Text encodation
240	Latch to EDIFACT encodation
241	ECI Character
242-255	Not to be used in ASCII encodation

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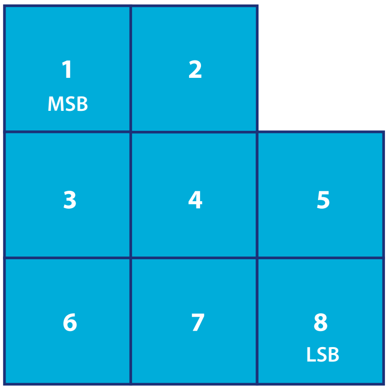
A.6 Structure of Codewords used in Data Matrix ECC 200

Extracted from the standard ISO/IEC 16022



LSB = Least significant bit

MSB = Most significant bit

Figure 6 Representation of a codeword in a symbol character for ECC 200

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A.7 Application Standard IFAH (Internation Federation for Animal Health)

By way of example, the Application Standard of the IFAH (International Federation for Animal Health) Guideline for Application of GS1 DataMatrix on Animal Health Products is summarized below. For full details refer to the complete guideline available from www.ifahsec.org

- **Data Structure and syntax:**
  - Usage characters: all characters from ASCII 128
  - Syntax and structure:
    - GS1 DataMatrix and GS1 Application Identifiers
    - Application Identifiers which may be used : AIs 01, 02, 10, 17 & 37
    - FNC1 Codeword 232 in 1st position (GS1 DataMatrix)
    - <GS> codeword 29 (as a separator character as required)

- **Mandatory data requirements:**
    - GTIN,
    - Batch/Lot number,
    - Expiration date

- **Format of DataMatrix :**
  - The number of rows and columns is determined by the amount of data encoded and the symbol can be square or rectangular form
  - X-dimension range of 0.19 mm to 0.38 mm (10 mils (0.254 mm) is recommended)

- **Human Readable Interpretation:**

All the required information (GTIN AI (01), batch number AI(10) and expiry date AI(17)) are to be printed in human legible characters in close proximity to the GS1 DataMatrix symbol. The recommended and minimum text character height are:

	Character Height (cm)	Character Height (in)	Character Height (points)
Recommended	0.2 cm	0.08 in	5.76 pts
Minimum	0.125 cm	0.05 in	3.6 pts

Marking techniques:

- Quality requirements:
  - All quality checks should be according to ISO/IEC 15415
  - The following aperture is set for verification:

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Aperture Diameter (in 0.001")/ Aperture ref Nº	Aperture Diameter (in mm)	X- dimension range (in inch)	X-dimension range (in mm)
03	0.075	0.004 to 0.007	0.100 to 0.180
05	0.150	0.0071 to 0.013	0.180 to 0.330
10	0.250	0.0131 to 0.025	0.330 to 0.635
20	0.500	0.0251 and larger	0.635 and larger

Example:

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

- Pass grades :
  - ISO/IEC 15415 Grade 1.5 (ANSI C) or better

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A.8 Use of GS1 DataMatrix for Healthcare Products

Working in close co-operation with healthcare regulators, hospitals, pharmacies and medical suppliers, GS1 has and continues to is develop standards to improve patient safety needs by using GS1 DataMatrix to encode the information such as, but not limited to, the following:

- AI (01) Global Trade Item Number (GTIN)
- AI (17) Expiration Date
- AI (10) Batch Number

The GTIN is a globally unique identification number for medical products and can be used to meet many requirements in the healthcare supply chain including but not limited to (refer to: http://www.gs1.org/healthcare for more detailed information) :

- Ensuring the right drug is used at the point of administration
- Providing efficiency in product ordering and cost re-imbursement schemes
- A globally recognized system of identification and bar coding for pharmaceutical and medical device traceability
- A reference key for ensuring compliance to any local regulatory requirements (e.g., Unique medical device identification - UDI - for traceability & efficient recall procedures), pharmaceutical traceability, etc.,

The expiration date and batch number are used in combination with the GTIN to provide traceability and ensure out-of-date products are never administered. For certain medical equipment (e.g., specialist medical devices), a GTIN and AI (21) Serial Number are being recommended.

For more information on the use of both GS1 DataMatrix and the recommended GS1 Application Identifiers in the healthcare sector please visit the *GS1 Healthcare User Group Website*: **http://www.gs1.org/sectors/healthcare/**

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A.9 GS1 DataMatrix Questions and Answers (Informative)

The examples that follow are intended to show the reader a method to approximate symbol parameters such as symbol size (by module), symbol dimension and symbol data capacity. However, these parameters depend on the characteristics of the specific data elements used and to the specific arrangement of these data within the data string.
Detailed information on the process for minimization of symbol size may be found in ISO/IEC 16022:2006 - Annex P, Encoding data using the minimum symbol data characters for ECC 200.

Note: The use of "off the shelf" encoding software (conforming to ISO/IEC 16022:2006) is an efficient way to obtain exact values for specific data content and arrangement.

Q.1: How much data can I get into a GS1 DataMatrix symbol with a 20 X 20 data region size?

Step 1: From Table 1.2.2-1, look down column "Symbol Size" until you find the row that contains Row 20 – Col 20
Step 2: Follow this row to the columns labeled Maximum Data Capacity to find the maximum numeric or alphabetic data capacity.

NOTE: For GS1 DataMatrix, the first character is the Function Code 1 (FNC1) character. This will reduce the maximum data capacity by 2 for numeric or by 1 for alphabetic encoding. Use of subsequent FNC1 and shift characters will also decrease the maximum data content by 2 numeric characters or 1 alphanumeric character per instance of use.

Step 3: The table shows that 44 numeric, minus 2 numeric for FNC1, for a total of 42 numeric data capacity; it shows 31 alphabetic, minus 1 alphabetic for FNC1, for a total of 30 alphabetic data capacity.

Symbol Size*		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity		% of codewords used for Error Correction	Max. Correctable Codewords
							Num.	Alphanum.		Error/Erasure
Row	Col	Size	No.		Data	Error	Cap.	Cap.		
10	10	8x8	1	8x8	3	5	6	3	62.5	2/0
12	12	10x10	1	10x10	5	7	10	6	58.3	3/0
14	14	12x12	1	12x12	8	10	16	10	55.6	5/7
16	16	14x14	1	14x14	12	12	24	16	50	6/9
18	18	16x16	1	16x16	18	14	36	25	43.8	7/11
20	20	18x18	1	18x18	22	18	44	31	45	9/15
22	22	20x20	1	20x20	30	20	60	43	40	10/17

Example A.9-1.1 Data Capacity

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Q.2: I want to print a GS1 DataMatrix symbol with symbol size of 18 X 18. I only have enough space to print a symbol with total size of 5.08 mm X 5.08 mm (0.2" X 0.2"); what X dimension will allow me to print this symbol?

Step 1: The number of modules, per side, is the value of the symbol size plus 2 (for quiet zones) for each dimension, so the number of modules required to print a symbol size of 18 X 18 is 20 modules X 20 modules.
Step 2: Divide the length (l) given by the number (n) of modules to obtain the module size (X)

$$X = l/n = 5.08 \text{ mm}/ 20 = 0.254 \text{ mm } (0.010")$$

Q.3: I want to print a GS1 DataMatrix symbol containing a GTIN and a 10 digit serial number:

1.What is the smallest square symbol size that I can use?
2.How large will the symbol be if my X dimension is 0.254 mm (0.010")?

Step1: To encode GTIN + Serial Number, determine the total amount of data needed to encode the GS1 DataMatrix symbol:

Element	Number of Codewords
<FNC1>	1
<AI 01>	1
<GTIN>	7
<AI 21>	1
<Serial Number>	5
Total	**15**

Example A.9-3.1 Symbol Size Calcualtion

Step 2: Using Table 1.2.2-1 find the smallest size symbol that will support the number codewords required. Under Total Codewords – Data, the symbol size supporting 18 codewords is the smallest symbol that will support 15 codewords. The Symbol Size column shows that this is an 18 X 18 symbol.

The final symbol size, including quiet zones, is 20 X 20.

Symbol Size*		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity		% of codewords used for Error Correction	Max. Correctable Codewords Error/Erasure
Row	Col	Size	No.		Data	Error	Num. Cap.	Alphanum. Cap.		
10	10	8x8	1	8x8	3	5	6	3	62.5	2/0
12	12	10x10	1	10x10	5	7	10	6	58.3	3/0
14	14	12x12	1	12x12	8	10	16	10	55.6	5/7
16	16	14x14	1	14x14	12	12	24	16	50	6/9
18	**18**	16x16	1	16x16	**18**	14	36	25	43.8	7/11
20	20	18x18	1	18x18	22	18	44	31	45	9/15
22	22	20x20	1	20x20	30	20	60	43	40	10/17

Example A.9-3.2 Symbol Size Calculation

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Step 3: Calculate the symbol dimension for x-dimension of 0.254 mm (0.010”):

The symbol dimension (D) is the total number of modules (m) times the X-dimension.

D = 20 * 0.254 mm = 5.08 mm (0.20”)

Therefore, the final symbol size is 5.08 mm X 5.08 mm (0.20” X 0.20”)

Q.4: I want to print a GS1 DataMatrix symbol containing a GTIN and an 8 alphanumeric character serial number:

1.What is the smallest square symbol size that I can use?

2.How large will the symbol be if my X dimension is 0.254 mm (0.010”)?

Step1: To encode GTIN + Serial Number, determine the total number of codewords needed to encode the GS1 DataMatrix symbol:

Element	Data	Number of Codewords
<FNC1>	1 aplha (2 digit equivalent)	1
<AI 01>	2 digits	1
<GTIN>	14 digits	7
<AI 21>	2 digits	1
<Shift to alpha>	1 alpha	1
<Serial Number>		8
Total		**19**

Example A.9-4.1 Symbol Data Size Calculation

Step 2: Using Table 1.2.2-1 find the smallest size symbol that will support the number of codewords required. Under Total Codewords – Data, the symbol size supporting 22 codewords is the smallest symbol that will support 21 codewords. The Symbol Size column shows that this is a 20 X 20 symbol.

The final symbol size, including quiet zones, is 22 X 22.

Symbol Size*		Data Region		Mapping Matrix Size	Total Codewords		Maximum Data Capacity		% of codewords used for Error Correction	Max. Correctable Codewords Error/Erasure
							Num.	Alphanum.		
Row	Col	Size	No.		Data	Error	Cap.	Cap.		
10	10	8x8	1	8x8	3	5	6	3	62.5	2/0
12	12	10x10	1	10x10	5	7	10	6	58.3	3/0
14	14	12x12	1	12x12	8	10	16	10	55.6	5/7
16	16	14x14	1	14x14	12	12	24	16	50	6/9
18	18	16x16	1	16x16	18	14	36	25	43.8	7/11
20	**20**	18x18	1	18x18	**22**	18	44	31	45	9/15
22	22	20x20	1	20x20	30	20	60	43	40	10/17

Example A.9-4.2 Symbol Size Calculation

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Step 3: Calculate the symbol dimension for X-dimension of 0.254 mm (0.010"):

The symbol dimension (D) is the total number of modules (m) times the X dimension.

D = 22 * 0.254 mm = 5.59 mm (0.22")

Therefore, the final symbol size is 5.59 mm X 5.59 mm (0.22" X 0.22")

Encoding Example (Informative)

In this example, we will encode data in a series of length 6, with information "123456".

- Step 1: Data encodation

ASCII representation of the data is:

Data Characters: '1' '2' '3' '4' '5' '6'

Decimal: 49 50 51 52 53 54

The ASCII encodation converts the 6 characters into 3 bytes. This is done through the following formula

Codeword = (numerical value of digit pairs)+ 130

So, the details of this calculation are as follows:

"12" = 12 + 130 = 142

"34" = 34 + 130 = 164

"56" = 56 + 130 = 186

Therefore, the data stream after data encodations is:

Decimal: 142 164 186

Consulting the configuration table for Data Matrix (see the table of Data Matrix ECC 200 symbol attributes), we can see that 3 data codewords correspond to the capacity of a 10 lines x 10 columns symbol. Similarly that symbol carries 5 error correction codewords. If the encoded codewords were smaller than the available capacity, the remaining space should be filled with additional error correction codewords.

- Step 2: Error correction

By using the Reed-Solomon algorithm (see Annex E from Standard ISO/IEC 16022), the 5 error correction codewords give us the following total chain:

Codeword:	1	2	3	4	5	6	7	8
Decimal:	142	164	186	114	25	5	88	102
Hex: 8E	A4	BA	72	19	05	58	66	

On the other hand, the binary translation (see, The International Standard ISO/IEC 646 for representation of each character (hex, decimal, octal and binary)) would be:

10001110 10100100 10111010 01110010 00011001 00000101 01011000 01100110

- Step 3: Matrix Building

The final binary codewords are placed in the matrix as symbol characters according to the algorithm described in Annex F from Standard ISO/IEC 16022 (F.3), where 1.1 corresponds to the 1st bit of the first codeword, 1.2 corresponds to the 2nd bit of the first codeword, 1.3 corresponds to the 3rd bit of the first codeword etc. The final matrix would be:

2.1	2.2	3.6	3.7	3.8	4.3	4.4	4.5
2.3	2.4	2.5	5.1	5.2	4.6	4.7	4.8
2.6	2.7	2.8	5.3	5.4	5.5	1.1	1.2
1.5	6.1	6.2	5.6	5.7	5.8	1.3	1.4
1.8	6.3	6.4	6.5	8.1	8.2	1.6	1.7
7.2	6.6	6.7	6.8	8.3	8.4	8.5	7.1
7.4	7.5	3.1	3.2	8.6	8.7	8.8	7.3
7.7	7.8	3.3	3.4	3.5	4.1	4.2	7.6

This will lead to a following pattern:

1	0	0	1	0	1	1	0
1	0	0	0	0	0	1	0
1	0	0	0	1	1	1	0
1	0	0	0	0	1	0	0
0	0	0	0	0	1	1	1
1	1	0	1	1	0	0	0
1	1	1	0	1	1	0	0
0	0	1	1	1	0	1	0

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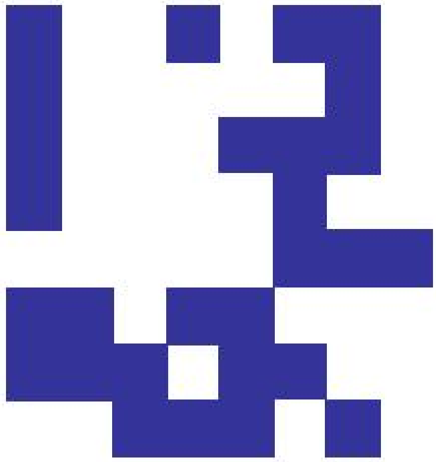
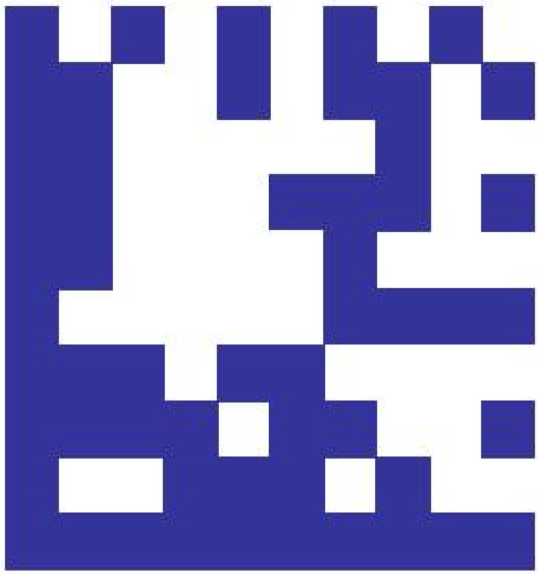
After colouring the patterns which are numbered 1:



Finally we add the finder pattern to cover the symbol above :



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Bibliography

The documents listed below are either directly or indirectly quoted within the document.

- GS1 General Specifications
- ISO/IEC 16022:2006 Information technology – Data Matrix bar code symbology specification
- ISO/IEC 15415 Bar code print quality test specification — Two-dimensional symbols
- ISO/IEC 15418 GS1 Application Identifiers and ASC MH 10 Data Identifiers and Maintenance
- ISO/IEC 15434 Syntax for high-capacity ADC media
- Application Standard: IFAH (International Federation for Animal Health) Version 1, 01/2005
- Semiconductor Association (SEMI): SEMI T2-0298E Marking wafers with a Data Matrix code
- USA's Department of Defence: MIL STD 130 Identification Marking of U.S. Military Property
- Electronics Industry Association (EIA): EIA 706 Component Marking
- The [USA's] National Aeronautics and Space Administration: NASA STD 6002 Applying Data Matrix Identification Symbols for Aerospace products

Glossary of Terms

The list below aims to provide the reader with summary of the technical terms and acronyms used in the context of GS1 Data Matrix. The objective is to aid the understanding and ensure unambiguous use of terminology throughout the document.

Term	Definition
2-Dimensional Symbology	Optically readable symbols that must be examined both vertically and horizontally to read the entire message. Two-dimensional symbols may be one of two types: matrix symbols and multi-row symbols. Two dimensional symbols have error detection and may include error correction features.
alphanumeric (an)	Describes a character set that contains alphabetic characters (letters), numeric digits (numbers), and other characters, such as punctuation marks.
aperture	A physical opening that is part of the optical path in a device such as a scanner, photometer, or camera. Most apertures are circular, but they may be rectangular or elliptical.
attribute	An Element String that provides additional information about an entity identified with a GS1 Identification Key, such as Batch Number associated with a Global Trade Item Number (GTIN).
Automatic Identification and Data Capture	A technology used to automatically capture data. AIDC technologies include bar code symbols, smart cards, biometrics and RFID.
Bar Code Verification	The assessment of the printed quality of a bar code based on ISO/IEC standards using ISO/IEC compliant bar code verifiers.
Batch / Lot	The batch or lot number associates an item with information the manufacturer considers relevant for traceability of the trade item. The data may refer to the trade item itself or to items contained in it.
carrier	The party that provides freight transportation services or a physical or electronic mechanism that carries data.

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Term	Definition
Check Digit	A digit calculated from the other digits of an Element String, used to check that the data has been correctly composed. (See GS1 Check Digit Calculation.)
concatenation	The representation of several Element Strings in one bar code symbol.
Configuration	Size and Type of a given symbol together.
coupon	A voucher that can be redeemed at the Point-of-Sale for a cash value or free item.
customer	The party that receives, buys, or consumes an item or service.
data carrier	A means to represent data in a machine readable form; used to enable automatic reading of the Element Strings.
data character	A letter, digit, or other symbol represented in the data field(s) of an Element String.
Data Matrix	A standalone, two-dimensional matrix symbology that is made up of square modules arranged within a perimeter finder pattern. Data Matrix ISO version ECC 200 is the only version that supports GS1 System identification numbers, including Function 1 Symbol Character. Data Matrix Symbols are read by two-dimensional imaging scanners or vision systems.
Full String	The data transmitted by the bar code reader from reading a data carrier, including symbology identifier and Element String(s).
Function 1 Symbol Character (FNC1)	A symbology character used in some GS1 data carriers for specific purposes.
Fuzzy Logic	Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic.
GS1 Application Identifier	The field of two or more characters at the beginning of an Element String that uniquely defines its format and meaning.
GS1 Application Identifier data field	The data used in a business application definied by one application identifier.
GS1 Check Digit Calculation	A GS1 System algorithm for the calculation of a Check Digit to verify accuracy of data. (e.g.: Mod 10, Price check digit).
GS1 Company Prefix	Part of the GS1 System identification number consisting of a GS1 Prefix and a Company Number, both of which are allocated by GS1 Member Organisations.
GS1 DataMatrix	GS1 implementation specification for use of Data Matrix
GS1 Global Office	Based in Brussels, Belgium, and Princeton, USA, is an organisation of GS1 Member Organisations that manages the GS1 System.
GS1 Identification Key	A numeric or alphanumeric field managed by GS1 to ensure the global, unambiguous uniqueness of the identifier in the open demand or supply chain.
GS1 Identification Keys	A globally managed system of numbering used by all GS1 Business Units to identify trade items, logistic units, locations, legal entities, assets, service relationships, and more. The Keys are built by combining GS1 member company identifiers (GS1 Company Prefix) with standards based rules for allocating reference numbers.
GS1 Member Organisation	A member of GS1 that is responsible for administering the GS1 System in its country (or assigned area). This task includes, but is not restricted to, ensuring user companies make correct use of the GS1 System, have access to education, training, promotion and implementation support and have access to play an active role in GSMP.

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Term	Definition
GS1 Prefix	A number with two or more digits, administered by GS1 that is allocated to GS1 Member Organisations or for Restricted Circulation Numbers.
GS1 System	The specifications, standards, and guidelines administered by GS1.
Human Readable Interpretation	Characters, such as letters and numbers, which can be read by persons and are encoded in GS1 AIDC data carriers confined to a GS1 standard structure and format. The Human Readable Interpretation is a one-to-one illustration of the encoded data. However Start, Stop, shift and function characters, as well as the Symbol Check Character, are not shown in the human readable interpretation.
Identification number	A numeric or alphanumeric field intended to enable the recognition of one entity versus another.
Linear Bar Code	Bar Code symbology using bars and spaces in one dimension.
Magnification	Different sizes of bar code symbols based on a nominal size and a fixed aspect ratio; stated as a percent or decimal equivalent of a nominal size.
Module	The narrowest nominal width unit of measure in a bar code symbol. In certain symbologies, element widths may be specified as multiples of one module. Equivalent to X-dimension.
Point-of-Sale (POS)	Refers to the retail checkout where omnidirectional bar codes must be used to enable very rapid scanning or low volume checkout where linear or 2D matrix bar codes are used with image-based scanners.
Physical Dimensions	The area of the symbol to print
Quiet Zone	A clear space which precedes the Start Character of a bar code symbol and follows the Stop Character. Formerly referred to as "Clear Area" or "Light Margin."
Quiet Zone Indicator	A greater than (>) or less than (<) character, printed in the human readable field of the bar code symbol, with the tip aligned with the outer edge of the Quiet Zone.
scanner	An electronic device to read bar code symbols and convert them into electrical signals understandable by a computer device.
Separator Character	Function 1 Symbol Character used to separate certain concatenated Element Strings, dependent on their positioning in the GS1 Bar Codes.
serial number	A code, numeric or alphanumeric, assigned to an individual instance of an entity for its lifetime. Example: Microscope model AC-2 with serial number 1234568 and microscope model AC-2 with serial number 1234569. A unique individual item may be identified with the combined Global Trade Item Number (GTIN) and serial number.
special characters	Special characters that are designated by the symbology specification.
Size	Number of row and columns in a Data Matrix Symbol
substrate	The material on which a bar code is printed.
supplier	The party that produces, provides, or furnishes an item or service.
symbol	The combination of symbol characters and features required by a particular symbology, including Quiet Zone, Start and Stop Characters, data characters, and other auxiliary patterns, which together form a complete scannable entity; an instance of a symbology and a data structure.
symbol character	A group of bars and spaces in a symbol that is decoded as a single unit. It may represent an individual digit, letter, punctuation mark, control indicator, or multiple data characters.

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Term	Definition
Symbol Check Character	A symbol character or set of bar/space patterns included within a GS1-128 or GS1 DataBar Symbol, the value of which is used by the bar code reader for the purpose of performing a mathematical check to ensure the accuracy of the scanned data. It is not shown in Human Readable Interpretation. It is not input to the bar code printer and is not transmitted by the bar code reader.
Symbol Contrast	An ISO 15416 parameter that measures the difference between the largest and smallest reflectance values in a Scan Reflectance Profile (SRP).
symbology	A defined method of representing numeric or alphabetic characters in a bar code; a type of bar code.
symbology element	A character or characters in a bar code symbol used to define the integrity and processing of the symbol itself (e.g., start and stop patterns). These elements are symbology overhead and are not part of the data conveyed by the bar code symbol.
symbology identifier	A sequence of characters generated by the decoder (and prefixed to the decoded data transmitted by the decoder) that identifies the symbology from which the data has been decoded.
Type	Square or Rectangular in terms of shape
X-dimension	The specified width of the narrow element in a bar code symbol.
YAG Laser	YAG (neodymium-doped yttrium aluminium garnet; Nd:Y3Al5O12) is a crystal that is used as a lasing medium for solid-state lasers. The dopant, triply ionized neodymium, typically replaces yttrium in the crystal structure of the yttrium aluminium garnet, since they are of similar size.

(*) Although Data Matrix differs in many ways from traditional linear bar codes, the terminology of "bar code" has been maintained in this guide (in accordance with the vocabulary of the Data Matrix technical standard ISO/IEC16022)

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