

The logo graphic features a stylized, overlapping circular shape in white and blue. The word "Intermec" is written vertically in a bold, sans-serif font, with the letters in white and the background in blue.

Intermec

White
Paper

**SIZING APPLICATIONS
FOR 2D BARCODE SYMBOLS**

Intermec

PREFACE

AIM's Technical Symbology Committee and other industry associations continue to publish a wealth of technical specifications on two dimensional (2D) symbologies. This white paper, "Sizing Applications for 2D Symbols," presents a non-technical perspective and working knowledge for potential users of 2D codes. It compares the relative merits of 2D symbols to linear codes, outlines the basics of popular 2D codes today, and highlights the issues to consider when specifying which codes are well suited for typical applications.

The paper also presents simple calculations to determine the relative "size" of each 2D symbology addressed including PDF417, Data Matrix and Code One. Given this information – the number and type of characters to encode, the required X-dimension of the symbol and other factors – a quick estimate can be made to determine whether a specific 2D, "scaleable" symbology will fit on a "label" and work within potential user's application.

The development of 2D codes and the technical advancements for bar code printing and decoding them are cutting edge. For this reason, the value they can bring to the Auto ID arena has been, in some cases, greatly exaggerated among industry sources – even to the point of discounting tried and true linear codes as a technology of the past. This primer is designed to give you a clear, in-depth explanation of 2D symbologies and associated technologies. It will help you make an informed analysis about how 2D codes could be considered for your applications.

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INTRODUCTION

When it comes to 2D symbologies, less is more: more information in much less space. Two dimensional symbols may be less costly to print because they require less label space, but considerably more expensive to read based on the complexity of developing decode algorithms and available scanners. As more suppliers offer 2D scanners, prices for those which scan PDF417 in particular are being driven down close to the price level of input devices that decode linear symbologies.

Applications employing 2D codes present other tradeoffs over those using linear bar codes. Two dimensional symbols that provide a portable data file, such as PDF417 presents a shift away from a "license plate" bar code, which references additional information on an external database, the data contained within the symbol is limited to size constraints of the label. In addition, that data can be more cumbersome and costly to update.

What are 2D Symbologies?

Two dimensional codes have been classified by their relative geometry. The two most popular types are covered in this paper: Stacked codes and matrix codes.

Stacked codes are made up of two or more rows of bars and spaces that are "stacked" on each other – sometimes referred to as "stacked linear". Examples of stacked codes are Code 49, Code 16K and PDF417.

Matrix codes encode information using fixed-width light and dark cells. Some experts consider matrix codes to be "true" 2D codes. Example of matrix codes include Data Matrix, MaxiCode, Aztec Code, QR Code and Code One.

The Case for 2D Codes

You may ask, "why 2D?" And, "what can 2D codes do that can't be solved with 1D codes?" Answering these questions requires defining the specific Automated Data Collection (ADC) application problem(s) you want to solve. The more you know about the basic characteristic of popular 2D codes, their advantages and limitations, the more balanced perspective you'll gain for choosing the right symbol, shape and size for a given ADC application. Issues to consider are label size omnidirectional scanning, and portable data files.

Small Label Requirements

Two dimensional symbols can be used on labels with limited space, less than .75 inches (1.9 cm) square, and when there is the need to capture a small amount of data, less than 50 characters. In this application, a scaleable matrix code such as Data Matrix, Aztec Code, QR Code, or Code One works best because a matrix code offers much higher density than 2D stacked codes such as PDF417, which are designed to encode large amounts of data. Code 49 or Code 16K should also be considered to address small space requirements if you need to encode a more limited number of characters. MicroPDF417, new stacked symbology which is undergoing standardization, could also be considered for small space applications in which the symbol data capacity required is limited to 250 alphanumeric characters or 3 digits. An example of an application requiring small labels is to track manufacturer, item code, and traceability code on an electronic component.

Omnidirectional Scanning Capability

Because 2D matrix codes require scanning by a CCD "camera" image device, vendors developed an omnidirectional scanning capability. This capability allows random label orientation on an object, important for high-speed, "over-the-belt" scanning applications where it is impractical to maintain an exact position of labeled items on a conveyor. Imager technology also helps hand-held scanning situations where it is inconvenient or impossible to read the symbol within a horizontal or vertical orientation. Of course, CCD imagers are not limited to matrix codes; they can also onmi-directional scan 1D stacked symbols, such as Code 49 and PDF417 as well as linear bar codes, such as Code 3, Code 128, Interleaved 2 of 5 and others.

The Need for a Portable Data File

With their heightened data capacity, 2D symbols can support freestanding systems driven entirely by information carried on a label. The support contrasts with accessing computerized lookup files, also known as the “license plate” paradigm, inherent in linear bar code symbologies. When large amounts of data (more than 50 characters) must be retrieved, a 2D code can serve as a portable data file.

A larger 2D label application is the Material Safety Data Sheet (MSDS) specification sheets required by the government for hazardous materials such as chemicals, compounds and paints. Although PDF417 is not meant to necessarily replace the need for human readable text, this 2D code is a recommended standard for this application. Although not laser scannable, Data Matrix Aztec Code, QR Code and Code One can also be considered portable data files as well as other high capacity stacked and matrix symbols which are beyond the scope of this paper.

Basics of Popular 2D Symbols

Two Dimensional bar codes have been developed, placed in the public domain and published as AIM standards since 1987. These codes can be classified into two groups: stacked codes, sometimes referred to as “stacked linear”, and matrix codes. Code 49 was the first 2D stacked bar code invented by Intermec in 1987, followed by Code 16K developed by Laserlight Systems in 1988. PDF417, developed by Symbol Technologies in 1992, is also a stacked code, but it can accommodate a much higher data capacity (over 1800 characters) in comparison to Code 49 or Code 16 K, which can encode around 50 characters given reasonable symbol density.

Matrix codes also can hold large amounts of data, but within a much smaller size. These codes, such as Data Matrix, MaxiCode, Aztec Code, QR Code, and Code One, require reading by a 2D imaging device.

Reduced Quiet Zones for matrix codes (except for Aztec Code and Code One in which none is required) allow symbol location in much closer proximity to surrounding text and/or graphics. Each 2D matrix code has a unique “finder pattern” or recognition pattern that reference the symbol type for the scanner.

MaxiCode has three concentric circles or a “bulls-eye” pattern; Data Matrix uses an “L” pattern bordering the left and bottom edge, Aztec Code uses a square bulls-eye; QR Code uses three square patterns the corners of the code; and Code One uses a series of horizontal lines (from three to six depending on the version) and from two to fourteen vertical recognition patterns.

PDF417

Developed in 1992 by Symbol Technologies, PDF417 is a multi-row, variable-length “stacked” symbology. The symbol is composed of a stack of 3 to 90 rows. A PDF417 symbol character, or codeword, consists of 17 modules arranged into four bars and four spaces.

PDF417 offers a maximum data character capacity of 1,850 text characters, or 2,710 digits or 1,108 bytes. Error correction levels are user selectable and can be set from 0 (zero) or no error correction to 8 (eight), the highest level. The higher the error correction level, the greater the data redundancy. Higher error correction levels built into the symbol facilitate faster decoding. However, more data redundancy requires more rows, making the PDF417 symbol longer. Lower than recommended error correction levels may be considered for closed systems applications, while high levels are advised in applications where label damage is more likely. A quiet zone of two X-dimensions is required around the symbol.

It is important to design a PDF417 symbol with an aspect ratio and X dimension that is not only compatible with the label format but is also optimized for the designated scanner. For example, some linear CCD scanners read PDF417 symbols best when they are printed with an aspect ratio of 4:1 or 3:1 and no wider than 3 inches (7.6 cm) for non contact scanning of 7.5 mil code. Given that the optics of an imager accommodate a specific mil size of a PDF417 symbol, the device will perform best when the entire code is focused within its field of view. In general, PDF417 symbols should be printed with the largest X-dimension practical given label and package constraints and sized roughly square to ensure optimum scanning performance.

When referring to 2D codes, Aspect Ratio (expressed as X:Y) is either the ratio of module height to module width, or the height-to-width ratio of the entire symbol.

PDF417 can be scanned by a laser scanner, linear CCD scanner, or imaging device.

Another stacked, or multi-row symbology, closely related to PDF417 MicroPDF417. This symbology, invented by Symbol Technologies, can encode 150 bytes, 250 alphanumeric characters, or 366 digits. MicroPDF417 shares many of the same attributes as PDF417 including encodation modes, error correction and symbol character sets. MicroPDF417 is distinctive from PDF417 in that the symbol may only be produced within specific row, column and error correction codeword combinations, up to a maximum of four data columns by 44 rows.



Data Matrix

Data Matrix is a 2D matrix symbol developed in 1989 by International Data Matrix. These symbols are always square – given error checking and correcting (ECC) which can be square or rectangular – and bordered on two sides with a dark recognition or finder pattern. Data Matrix offers a maximum data character capacity of 2,335 text characters, or 3,116 digits, or 1556 bytes. However, in selecting the size and density for the symbol the available space on a label, form, or object should be considered as well as optimizing an imager's operating performance.

A quiet zone of one X-dimension is required around the perimeter of Data Matrix symbol. For new and/or open systems type applications, ECC-200 is recommended.

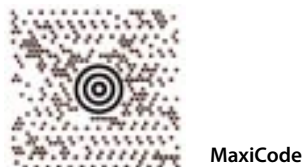
Visually identifying whether a Data Matrix symbol is ECC 000-140 or ECC 200 is as easy as looking at the right upper square. If the square is white, the symbol is ECC 200. If an ECC 200 symbol is reversed (a white image on a black background), also called "reflectance reversal" the upper right square is black.

Larger square ECC 200 symbols, those requiring at least 32 rows and 32 columns, will include alignment patterns to separate the data regions. A finder pattern surrounds each data region. Symbols with more than 104 rows and columns have 36 data regions.



MaxiCode

MaxiCode is a 2D matrix symbol developed by Onipolar and deployed by United Parcel Service (UPS) in 1987. MaxiCode symbols have a fixed size of 1.1 inches by 1.05 inches (28.14mm wide x 26.91mm high) and a 35 mil X-dimension. The symbol has a maximum data capacity of 93 alphanumeric characters and 138 numeric characters depending on the level of error correction. MaxiCode symbols have 866 hexagonal modules arranged in 33 rows around a central finder pattern – Three concentric dark rings, which appear like bulls-eye. A quiet zone of at least one cell borders the symbol. One two error correction levels may be selected, Standard Error Correction (SEC) or Enhanced Error Correction (EEC). MaxiCode symbols are used to encode information including a shipper's account number, the buyer's address, the deliver service level, etc., which travels with the package. This creates a package identification which becomes linked with sortation instructions as parcels are routed throughout the conveyor sortation process.



Code One

Code One is a 2D matrix symbol developed in 1991 by Laserlight. Code One is a rectangular step symbol where each symbol is a specified number of characters. Symbols are specified with data capacities of 19, 44, 91, 182, 370, 732 and 1480 bytes of data. The number of characters that require encoding determine which version of the symbol should be used among the ten different versions and 14 sizes of Code One. The smallest and largest versions can contain 20 and 2,040 symbol characters respectively. (A symbol character is 8 modules in case of Code One).

Code One versions A, B, C, D, E, F, G and H are suitable for normal applications using most printing technologies. The version used for a given application should usually be the smallest that can encode the required data. Error correction levels are fixed according to each Code One version. Code One does not require a quiet zone, which saves space around the symbol for labeling and direct marking applications.

Other 2D symbologies are undergoing various stages of technical standardization, including Aztec Code and QR Code. While no application standards have been built around these matrix symbologies they could be considered viable candidates to satisfy specific applications.



Code One

Aztec Code

Aztec Code, invented and announced in 1995 by Welch Allyn, has been characterized as a “second generation” 2D matrix code. Aztec Code symbols are nominally square, scaleable, and can encode up to 3,067 text characters, 3,832 digits, or 1,914 bytes. Symbols range in size from 15 x 15 modules up to 151 x 151 modules. Error Corrections user selectable. The symbology is made of square modules with a square bulls-eye finder pattern in the center. No quiet zone around the symbol is required.



Aztec Code

QR Code

Quick Response Code (QR Code) is a square matrix symbology invented by Denso (then Nippondenso) and announced in 1994. The symbology is most easily recognized by its finder pattern, which consists of three, square position detection patterns located on three corners of the code. In addition to a maximum 4,396 text characters, 7,089 digits and 2,953 bytes, QR code can encode a maximum of 1,817 Kanji and Katakana characters. Four levels of error correction available. A quiet zone of four modules wide is required around the perimeter of the symbol. There are two models of QR Code: Model 1 and Model 2. Model 2 is an enhancement of Model 1 and is recommended for all new applications and those within an open systems environment.



QR Code

Error Correction, Error Detection and Encryption

In general, the higher the Error Correction level the larger the symbol. The exception is MaxiCode, which uses a fixed symbol size, and level of error correction, reducing the symbol capacity available for data characters. Although smaller error correction levels can be used to shrink symbol sizes, smaller levels provide less data redundancy and less assurance that a damaged symbol can be decoded. The amount of data encoded in a symbol, how well a symbol is printed, the environment and handling to which it is exposed, and its expected application life are all factors to consider in specifying error correction levels. In linear bar codes, the error correction component is inherent in the vertical height of the individual bars and spaces. The taller the bars and spaces, the more likely a scanner can decode the bar code.

Encryption is a method of “scrambling” the data before it is encoded a symbol. Encryption is not contained within a symbol’s structure itself. This can prevent decoding data within a given symbol – an added security measure for cases such as when the symbols are photocopied by unauthorized person. Decoding the encrypted data requires the use of a decryption key.

Symbol Sizes: A Simple Comparison

A relative size comparison among the different codes can be seen using similar X-dimensions (except for MaxiCode which has a fixed magnification of 35 mils) and roughly 100 characters for each of the 2D symbols. Notice that the matrix symbols are much smaller given the same number of characters than PDF417 code.

Application Standards

The development of application standards by various industry groups will continue to encourage market acceptance for the technology. In addition, as more products become available to print and read public throughout the supply chains that apply 2D technology. This section describes the most significant application standards.

ANSI MH10.8.3

ANSI MH10.8.3 is a material handling standard for 2D symbols with Unit Loads and Transport packages to convey data between trading partners. Expected beneficiaries of this standard include users with applications in shipping, sortation, tracking, transportation and receiving of unit loads and transport packages. Two dimensional symbols incorporated within this standard include PDF417 and MaxiCode. PDF417 is recommended for shipping labels and supplementing EDI transactions. MaxiCode is recommended for sortation and tracking. See the section “Sources for More Information” to obtain a copy of the ANSI MH10.8.3 specification

AIAG (Automotive Industry Action Group)

The AIAG has developed specific application guidelines that use PDF417, Data Matrix and MaxiCode. Ten applications were defined and grouped into three process categories. These categories share similar attributes that are well suited to a given 2D symbology, including number of characters, label size constraints and error correction. For Category 1, part Marking and Tracking, Data Matrix is recommended. PDF417 is suggested for General Applications under Category 2 including Quality Conveyance, Production Evidence, Production Broadcast, Configuration Management, material Safety Data Sheets (MSDSs) and Shipping/EDI. For Category 3 applications, freight sortation and tracking, MaxiCode is recommended. See the section “Sources for More Information” to obtain a copy of the “AIAG B-13: 2 Symbology White Paper.”

When a 1D Code is Most Practical

Two dimensional codes offer higher data capacity, a better fit in tiny spaces (matrix symbols) and depending on the scanning device, the ability to be read without regard to orientation. Even with these advantages, 2D symbology developments may not replace most linear bar code applications within a reasonable time frame, if at all. Although an ADC application may appear to be suited for a 2D solution based on a specific symbology it is important to first consider all linear bar code options.

If you are considering using 2D as a portable data file, there may be relative advantages to having all information within the symbol itself. For example, a customer expecting a shipment may need to know how to handle a package throughout the transportation process. An on-line database records each scanned transaction related to the item bearing the symbol. However, a portable data file 2D code presumes no connection to a database. Instead, the information and how it should be handled is within the symbol. The issue is the degree to which a transaction is dynamic or static.

While 2D codes can be created by most bar code printing technologies and some direct marking techniques, the required hand-held scanner carry a premium price compared with equivalent linear scanner. If the orientation is not an issue in scanning a stacked code, a CCD scanner or laser scanner (either single line or rastering) is a more economical solution than a hand-held imager. However, the scan and decode transaction is much slower (given the several hundred characters encoded in a PDF417 symbol – the purpose for which this symbol was developed) compared to scanning linear codes (with a few characters using the same device). Hand-held imagers, even though they can omnidirectionally scan all bar code types (linear, stacked and matrix) may be slower yet, depending on the data capacity. As these factors indicate, the scanning performance tradeoffs should be weighed when choosing 2D over 1D. In general if the application requires encoding less than 50 characters or space is limited to an inch, linear codes should be considered unless a supplier compliance directive to use a specific 2D symbology is either strongly encouraged or required.

Fitting a 2D symbol on a Label

It is possible to estimate the relative size of a 2D code using manual methods (rather than resorting to trial and error methods by downloading parameters to a PC) to determine how large or small a given symbol will be printed. The size of specific 2D symbologies basically depends on three factors:

- A. Number and Type of Characters to Encode
- B. X-dimension (module width)
- C. Error Correction Level (data redundancy)

How to Size PDF417

1. In sizing a PDF417 symbol, determine the number of columns and rows required to encode the data. Each character type (alpha, numeric or ASCII) equates with a number of codewords.

Table 1: Codewords per Character Type

Character Type	Characters	Codewords
Alpha	1	.5263
Numeric	1	.3448
ASCII	1	.8333

2. Reference Table 2 (also on page 12 of the PDF417 specification) can determine the recommended error correction level based on the number of codewords.

Table 2: Recommended Error Correction Levels

Number of Data Codewords	Error Correction Level
1-40	2
40-160	3
161-320	4
321-863	5

3. Reference the number of error correction codewords required with error correction level (Table 3) (also on page 10 of the PDF417 specification).

Table 3: Error Correction Level

Error Correction Level	Number of Error Correction Codewords
2	8
3	16
4	32
5	64
6	128
7	256
8	512

The width and height of a PDF417 symbol may be calculated as:

$$\text{Symbol Width} = (17C + 69) X + 2Q$$

Symbol overhead is represented by 17, which is the number of modules or one codeword and 69 – the number of row and column indicators including start and stop patterns.

$$\text{Symbol Height} = RY + 2Q$$

Where:

C = Number of columns in the data region

R = Number of rows

X = X-dimension of the symbol

Y = Row height

Q = Size of Quiet Zone (minimum 2X)

PDF417 Example Calculation

1. Given 100 alphanumeric character, $100 (.5263) = 52.63$, rounded to 53 codewords (see Table 1).
2. With 53 codewords, the recommended error correction level is 3 (see Table 2).
3. With error correction of 3, 16 error correction codewords are required (see Table 3) for a total of 69 codewords ($53 + 16$).
4. Knowing that PDF417 requires complete rows, 69 codewords is the product of 3 columns by 23 rows [$(3)(23) = 69$].
5. Assigning an X-dimension of 15 mils for the code and adding a minimum quiet zone of 2X, we can enter all values to solve for height and width of the symbol. Note that the recommended minimum row height is 3X. In this case row height is $(3)(.015)$, yielding the result:

$$\text{Symbol Width} = 1.86 \text{ inches (4.7 cm)}[(17)(3) + 69](.015) + 2(.030)$$

$$\text{Symbol Height} = 1.10 \text{ inches (2.8 cm)}(23)(.045) + 2(.030)$$

- D. Error Correction Level (data redundancy) 15 mil X-dimension Error Correction level 3 Estimated PDF417 symbol size based on example calculation.

How to Size Data matrix (ECC-100)

1. Determine the number and type of characters to encode (Table 4):

Table 4: Character Capacity per Character Type

Character Type	Maximum Character Capacity
Alphanumeric	2335 characters
Numeric Only	3116 digits
Any ASCII character 8-bit 0-255	1556 characters

2. Reference Table 5 (also in Annex A.4 of the Data Matrix Specification), matching the character type and number with the symbol size, remembering that ECC 000-140 symbols have an odd number of rows and columns. The Error Correction overhead calculation has already been added to the Symbol Size. The error correction level is equated with the amount of expected symbol damage. As error correction levels increase, less data character capacity is available for given symbol row and column size, the physical size of the symbol increases and decoding time is slowed.

Table 5: ECC 100 Symbol Attributes

Symbol Size		Numeric	Alphanumeric	8-bit byte
Row	Column			
13	13	1	1	NA
15	15	8	5	3
17	17	16	11	7
19	19	25	17	11
49	49	300	200	131

3. Specify an X-dimension for the symbol.

Data Matrix Example Calculation (ECC-100)

1. Determine the number and type of characters to encode.
2. Referencing Table 6 (also on page 16 of the Data matrix specification) match the character type and number with the symbol size, remembering that square symbols have an even number of rows and columns, except for rectangular versions of ECC-200. The error correction overhead calculation has already been added to the symbol size.

Table 6: ECC-200 Symbol Attributes

Symbol Size		Numeric	Alphanumeric	8-bit byte
Row	Column			
10	10	6	3	1
12	12	10	6	3
14	14	16	10	6
16	16	24	16	10
18	18	36	25	16
20	20	44	31	20
22	22	60	43	28
24	24	72	52	34
26	26	88	64	42
32	32	124	91	60
36	36	172	127	84
40	40	228	169	112
44	44	288	214	142
48	48	348	259	172
52	52	408	304	202
64	64	560	418	278
72	72	736	550	366
80	80	912	682	454
88	88	1152	862	574
96	96	1392	1042	694
104	104	1632	1222	814
120	120	2100	1573	1048
132	132	2608	154	1302
144	144	3116	2335	1556
Rectangular Symbols				
8	18	10	6	3
8	32	20	13	8
12	26	32	22	14
12	36	44	31	20
16	36	64	46	30
16	48	98	72	47

3. Specify an X-dimension for the symbol.

Data Matrix Example Calculation (ECC-200)

This example calculation uses 100 alphanumeric characters. Because this is more than 91 and less than the maximum allowable (127, See Table 6), use 127 to reference the symbol size. In this case, the size 36 rows by 36 columns. Then using an X-dimension of 20 mils, the symbol would be .72 inches (1.8 cm) square $(36)(.020)$.

Data Matrix: ECC-200

100 alphanumeric characters

20 mil X-dimension

Estimated Data matrix ECC-200 symbol size based on example calculation

How to Size Code One

1. Determine the number and type of characters to encode – alphanumeric, numeric, or ASCII.
2. See Table 7 to determine the character capacity associated with each Code One Version.
3. Select the Code One version which is the smallest possible for encoding the required data. Each version of Code one can accommodate more numeric characters than alphanumeric characters, with full ASCII characters requiring the most space.

Table 7: Code One Character Capacity

Version	Alphanumeric	Numeric	Full ASCII
A	13	22	10
B	27	44	19
C	64	104	44
D	135	217	91
E	271	435	182
F	553	886	370
G	106	1755	732
H	2218	3550	1480

4. After selecting the code version, decide on an X-dimension of the symbol.
5. Based on the selected Code One version and X-dimension, reference Table 8 to calibrate the symbol width and height give the number and type of characters to encode.

Table 8: Code One Size per Version

Version	Module Width	Module Height
A	18	16
B	22	22
C	32	28
D	42	40
E	54	52
F	76	70
G	98	104
H	134	148

Code One Example Calculation (Version E)

This example uses an application that requires 200 alphanumeric characters and a symbol that must be printed with a 15 mil X-dimension.

Referencing Table 7, code version E corresponds with 200 alphanumeric characters. Two-hundred alphanumeric characters is more than code version D (135 characters) but less than the maximum allowable for version E (271 characters).

Table 8 shows the module widths and heights associated with each code version. In this case, version "E" has a module width of 54 and height of 52. The width of this code with a 15 mil X-dimension is .81 inches (2 cm) $[(54)(.015)]$; the height is .78 inches (2 cm) $[(52)(.015)]$

Code One: Version E

200 Alphanumeric Characters 15 mil X-Dimension

Estimated Code One symbol size based on example calculation.

2D Label Generation Software

Manually estimating the size of a 2D symbol for a potential applications is a valid approach for initial consideration of an appropriate symbology. However, entering the calculation values into label generation software is easy and provides the extra value of an actual sample label.

Printed symbols offer the best way to verify the size is right and how well they can be scanned for both decode time and accuracy of the data. For example, with a sample label you can determine if a symbol X-dimension is too small to be scanned easily, or the code is larger than an imager's field-of-view.

Numerous label generating software programs for 2D symbols are available. These software programs accommodate many of the popular 2D symbols including Code 49, Code 16K, PDF417, Data Matrix, MaxiCode and CodeOne.

Applications for 2D

In addition to understanding the different standards for 2D symbols, it's important to consider their potential application in your business. Although many other applications are possible, this discussion focuses on the most common: small item tracking, uses for portable data files and freight sortation.

Small Item Tracking

One of the best potential uses of 2D symbols is for labeling small items and other small space applications if there is no reasonably economical alternative. Parts tracking applications in particular are becoming the most popular application for 2D symbols. Data Matrix has been embraced as the standard symbology for small item tracking applications in a number of industry organizations including the Electronics Industry Association (EIA), Semiconductor Equipment and Materials International (SEMI) and the Automotive Industry Action Group (AIAG).

Electronic component Marking

Manufacturers are testing the use of small symbols, primarily Data Matrix, on various components from wafer marking using etched symbols to printed circuit boards needing label materials to withstand wave solder, high heat and caustic substances. In addition to tracking electronic component manufacturing and assembly processes, some chip makers are looking for symbols to help deter theft and verify who has proper title to these assets. Given the small symbol X-dimension required for small part marking, high-speed over-the-belt scanners with 2D symbols are most suitable for these applications.

Portable Data File

A portable data file may be appropriate when data must be physically associated with an item, such as an application in a remote location and the information is subject to relatively little change.

Material Safety Data Sheet (MSDS)

Using a PDF417 symbol to confirm the paperwork associated with a Material Safety Data Sheet (MSDS) provides users quicker access to the contents of hazardous materials – especially if they're in a remote location away from an electronic database. Encoding an abbreviated MSDS with PDF417 can provide information on the chemical and physical properties associated with the material as well as emergency response information.

Personal identification Cards

Over four million personnel identification cards have been issued by the U.S. Department of Defense (DOD). PDF417 is used to encode the person's name, rank, identification number, commissary privileges, a photograph. It is estimated that 15 million military personnel, dependents and retirees will be using these cards at military checkpoints, hospitals, commissaries, PX facilities and other locations.

A number of states, including Arizona, New York, Pennsylvania, Colorado, Connecticut and Florida, are printing PDF417 on auto drivers licenses. The information encoded in the symbol can be the entire human readable text on the card in addition to the driver's photo. As a form of personal identification, 2D encoded cards will be much more difficult to alter for fraudulent purposes compared with non-bar coded licenses. PDF417 has been standardized by the American Association of Motor Vehicle Administrators (AAMVA) for a variety of applications including vehicle registration, title transfers and license renewals.

Printing With 400 DPI Technology

Just as 2D symbols can provide more information in a smaller space, 400 DPI print technology provides a higher print resolution that allows small symbols to be decoded faster and more reliably with available scanners. For example, MaxiCode symbols printed with 400 DPI are more easily located by a scanner because the "bulls-eye" finder pattern circles have smoother edges. The hexagonal modules can also be printed more accurately with 400 DPI, a valuable feature for applications requiring small labels such as electronic component marking for wafer identifications such as unit dose pharmaceuticals and patient wrist bands.

1D CCD Scanners

If users need to scan both PDF417 and linear codes and a relatively small depth of field [out to 4 inches (10 cm)] is acceptable, CCD scanners provide a fast and economical solution. PDF417 symbols with a X-dimensions of 7.5 mil or greater and approximately square aspect ratios are recommended for optimum scan performance. Error correction levels of 6-8 are recommended for PDF417.

Rastering Laser Scanners

For PDF417 applications (combined with popular linear bar codes) requiring a longer depth of field and wider symbol width than a 1D CCD scanner can accommodate, a rastering laser scanner may be the more suitable.

Hand-held Imager

An imager is required for applications using matrix symbols or those needing omnidirectional capability with matrix, stacked, or 1D codes

Future Directions for 2D Symbologies

With the integration of public domain 2D symbologies into a breadth of application standards, solutions employing these codes should see steady growth. Advances in both hand held and fixed positions scanning technology as well downward price adjustments will help spur growth. As in any new technology, early adopters need to not only embrace the symbols but influence their use throughout various supply chains. Users who ultimately drive 2D applications want to know who's done it before. Understanding the successes of others and the pitfalls to avoid will instill the confidence users need to move forward in developing a data collection solution in which 2D is the best option. Promoting the value 2D codes bring to specific applications and the financial benefits gained from using these approaches will be the major contributor to market acceptance of this technology.

According to Venture Development Corp., the worldwide consumption of 2D products will grow at a compound annual growth rate of 35 percent within five years.

Venture Development Corp. also projects that while requirements for portable data bases and sortation are significant applications, the largest projected growth over the next five years for 2D is in small parts marking. And for small parts, Data Matrix will be among the predominate symbologies.

User education on 2D technology, its benefits and tradeoffs with other data collection methods including linear bar codes, is key to moving these symbols from a technical curiosity to an application reality. Understanding why a 1D code won't work, or is a non-preferred solution in a particular case should be a first step in exploring the possibilities with 2D. Users armed with this balanced perspective can more objectively evaluate the opportunities for 2D in comparison to other data collection technologies.

GLOSSARY OF 2D TERMS

Edited from published AIM Uniform Symbology Specifications (USS)

Alphanumeric:

The character set that contains the letters A-Z and the numbers 0-9.

ASCII Character Set:

128 characters including both control and printing characters.

Aspect Ratio:

Expressed as X:Y. When referring to 2D codes it is either the ratio of module height to module width or the height to width ratio of the entire symbol.

Check Character:

A character within a symbol whose value is used to perform a mathematical check to ensure the symbol has been decoded correctly.

Code Word:

A Symbol Character value

Element:

A single bar or space.

Element Width:

The thickness of an element measured from the edge closest to the symbol start character to the trailing edge of the same element.

Error Correction:

Also referred to as Data Redundancy; symbol characters reserved for error correction or detection. These characters are calculated mathematically from the other symbol characters.

Error Detection:

Also referred to as Data Security; keeps the symbol from being decoded as erroneous data. Error correction characters can be reserved for error detection, in which case they function as check characters.

Finder Pattern:

Also called Recognition Patter; used to help find the symbol, determine the symbol version, tilt and orientation, as well as provide additional reference points to calculate the data square positions to account for surface curvature.

Matrix Code:

An arrangement of regular polygon shaped cells where the center to center distance of adjacent elements is uniform. The arrangement of the elements represents data or symbology functions. Matrix symbols may include recognition patterns that do not follow the same rule as the other elements within the symbol.

Module:

The narrowest, nominal width unit of measure in a symbol. One or more modules are used to construct an element.

Numeric:

A character set including only number 0-9.

**Overhead:**

The fixed number of characters required for start, stop and checking a given symbol. For example, a symbol requiring a start/stop and two check characters contains four characters of overhead. To encode three characters in this symbol, seven characters must be printed.

Quiet Zone:

Spaces preceding the start character of a symbol and following a top character. Sometimes called the "Clear Area".

Stacked Code:

A long, multi-row symbol that is broken into sections which are stacked on upon another in a fashion similar to sentences in a paragraph.

Symbol Character:

A unique bar or space pattern defined for particular symbology. Depending on the symbology, symbol characters may have a unique associated symbol value.

X-Dimension:

The nominal dimension of the narrow bars and spaces in linear and 2D stacked codes. In 2D matrix symbols, the X-dimension is the height and width dimension of the smallest element because each module is square, except for MaxiCode modules which are hexagonal.

Sources for More information

Description
PDF417: AIM Uniform Symbology
Data Matrix: AIM USS
MaxiCode: AIM USS
Code One: AIM USS
Code 49: AIM USS
CODE 16K: AIM USS
ANSI MH10.8.3-1996 – Two Dimensional Symbols with Unit Loads and Transport Packages
EIA-706: Component Marking Standard
AIAG B-13: 2D Symbology White Paper**

Copies of AIM Uniform Symbology Specifications (USS) can be obtained from:

AIM USA
634 Alpha Drive
Pittsburgh, Pennsylvania 15238-2802
Phone: 4123-963-8588
Fax: 412.963.8753

Copies of the ANSI MH10.8.3 Specification can be obtained from:

ANSI – American national Standards Institute
11 West 42nd Street
New York, New York 10018
Phone: 212.642.4900
Home Page: www.ansi.org

Copies of the EIA-706 Component Marking Standard can be obtained from:

Electronic Industries Association
Engineering Department
2500 Wilson Boulevard
Arlington, Virginia 22201

Copies of the AIAG B-13 2D Symbology White Paper can be obtained from:

Automotive Industry Action Group
26200 Lahser Road, Suite 200
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