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Data Matrix sets the standard for challenging item identification

A rocket engine, an M-16 rifle, a stick of deodorant and a circuit board generally do not share much in common, but the manufacturers of those items and hundreds more in the electronics, semiconductor, aerospace, defense, pharmaceutical and consumer goods industries share a common solution to product traceability challenges. It is a Data Matrix symbol. Today, if you look carefully inside many such objects you'll see a tiny square made up of a collection of even smaller dots. Data Matrix symbols are used on thousands of diverse items to provide accurate identification, safeguard product integrity, provide critical maintenance information and even keep production processes flowing efficiently.

Data Matrix sets the standard for reliable, accurate and space-efficient identification. In fact, it is the standard specified by the Electronic Industries Association (EIA), Semiconductor Equipment Manufacturer's Institute (SEMI), Automotive Industry Action Group (AIAG), Society of Automotive Engineers (SAE), NASA, the Air Transport Association (ATA) and the U.S. Department of Defense (DoD), for meeting a variety of item traceability and lifetime identification requirements.

Many manufacturers in the aforementioned industries encourage – and often require – their suppliers to apply Data Matrix symbols to parts and components. Many suppliers are familiar with the technology and marking options. Companies shouldn't overlook the tremendous value Data Matrix can bring to their own internal operations. Data Matrix can help provide added visibility into production processes, help take errors and inconsistencies out of asset management, assist quality control processes and much more. To help you take advantage of Data Matrix, this article provides an overview of the technology and its capabilities, marking and reading options, standards and some helpful tips for integrating Data Matrix into your operations.

What is Data Matrix?

As noted above, Data Matrix is a two-dimensional (2D) bar code symbology laid out in a square or rectangular grid. Data is encoded on both the x and y axes in a series of dark and light blocks that make the symbol resemble a crossword puzzle (See Fig. 1). Therefore, Data Matrix symbols are not read with laser scanners, but rather with imagers, CCDs or other camera-based products that can "read" data contained in an area rather than a line. Symbols can be created with a variety of direct part marking (DPM) techniques and printed on labels and nameplates. Information capacity, compactness and generous reading tolerance sets Data Matrix apart from other bar code symbologies.

Figure 1: A Data Matrix symbol. The solid black lines on two axes help readers locate and properly decode the symbol.

Because information is encoded in two dimensions, Data Matrix has much more data capacity than common linear symbologies such as U.P.C. or Code 39. For example, 50 characters can be encoded in a Data Matrix symbol measuring just 6mm by 6mm (See Fig. 2). Contrast this with a common U.P.C. symbol, which only encodes 13 numeric characters and requires comparatively much more space to do so. Any alphanumeric ASCII character can be encoded in a Data Matrix symbol. The maximum data capacity is 1,556 bytes, yielding 2,335 alphanumeric characters or 3,116 numeric characters.

Figure 2: 50 characters encoded in a small symbol. Graphic is to scale but not actual size.

Manufacturers without high data capacity requirements prefer Data Matrix because it can provide basic identification in a very limited space. For example, one of our customers has a process that etches product serial numbers into circuit boards using symbols that are less than 2.8mm by 1.8mm, and reads them on a production line moving 20 inches per second. But Data Matrix can be used for much more than simple serial-number identification. Many organizations use it in applications that require a permanent but portable database to store configuration information, product genealogy, lot codes, production history and other data.

The data carrying capacity of Data Matrix helps make it extremely reliable. The symbology standard for Data Matrix includes provisions for encoding error detection and correction algorithms, which the user can set at different levels. As a result, Data Matrix symbols with scratches, tears, holes and stains can be successfully read without data loss, even if more than 20 percent of the symbol were to become damaged and unreadable.

Data Matrix also provides generous reading tolerances compared to other optical-based identification technologies. Successful reading of any bar code symbology always requires some contrast between light and dark elements, and the required contrast level varies with the symbology being read. Data Matrix can be read at lower contrast ratios than most bar code symbologies, which is a helpful feature for environments where symbols may be obscured by grease, dirt, paint and chemical coatings, and when the symbology is applied to metal and other reflective surfaces (See Fig. 3).

Low-contrast readability opens up the marking options you can use for creating a Data Matrix symbol. For example, such symbols can be marked directly onto parts and components through ink jet, laser and chemical etching, dot peening and other methods. On-demand bar code printers can also produce Data Matrix symbols on a variety of label media, even at small sizes.

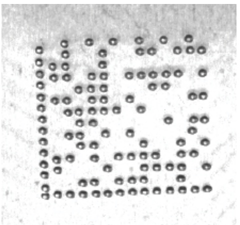

Figure 3: Low contrast is no problem for this Data Matrix symbol that was produced by dot peening on metal.

To read Data Matrix symbols, one needs to use some type of imager. Laser scanners can't be used because they generally are not effective reading in two dimensions. Laser scanners also typically require more contrast than many Data Matrix symbols provide. Acceptable imager options range from simple CCD-based readers, to fully integrated CMOS-based smart cameras, and even to high-end vision-systems utilizing separate lighting, lensing and image processors. Of course, imaging readers can be either manually-held or fixed mounted. Generally speaking, CCD-based devices are designed for reading bar codes, provide excellent performance, and cost considerably less than multi-functional vision and camera systems.

Everything about Data Matrix adds up to flexibility. The fact that you can read Data Matrix with CCD-or CMOS-based technology provides important budget flexibility whether your project concerns production control, work-in-process tracking, quality control or other applications in factory-floor environments. The reading performance and marking options allowed by Data Matrix also give you added flexibility for processing hard-to-recognize items. The symbology's significant data-carrying capacity gives you flexibility in placing a lot of information right onto the item needing to be tracked or identified.

Standards

For a bar code symbology to be used effectively across many organizations throughout an industry or supply chain, it must be based on a clear and open standard. Such standards provide structure and ensure that users and bar code technology providers alike have uniform performance. Data Matrix is an open standard symbology that is in the public domain. A series of ISO standards (ISO/IEC 16022, 15418, 15434 and 15415) have established the technical specifications for Data Matrix symbols, encoding, formatting and quality. Various industry standards continue to be built using ISO standards as the technical foundation for adding further specifications for symbol size, data content and usage requirements. Some leading Data Matrix industry standards and their uses are summarized in Figure 4.

Organization	Standard	Description
AAR	RP-021-04	Recommended practice for direct part marking
AIAG	AIAG B4	Parts identification and tracking
ATA	SPEC 2000	Electronic commerce, including permanent part ID
DoD	UID	Permanent & unique item identification
DoD	MIL-STD-130	Military property marking
EIA	EIA 706	Component marking
EIA	EIA 802	Product marking
ISO	ISO/IEC 16022	International Symbology Specification
ISO	ISO/IEC 15418	Symbol Data Format Semantics
ISO	ISO/IEC 15434	Symbol Data Format Syntax
ISO	ISO/IEC 15415	2-D Print Quality Standard
NASA	NASA STD 6002	Applying Data Matrix to aerospace parts
NASA	NASA-HDBK-6003	Applying Data Matrix by direct part marking
SAE	AS9132	Data Matrix quality requirements for part marking
SEMI	T1-95	Silicon wafer back surface marking
SEMI	T2-0298E	Silicon wafer marking
SEMI	T3-0302	Marking wafer box labels
SEMI	T7-0303	Marking double-sided polished wafers
SEMI	T8-0698E	Marking glass flat panel display substrates
SEMI	T9-0200E	Marking lead-frame strips
SEMI	T10-0801	Test method for direct part marking quality

Acronym key:
AAR: Association of American Railroads
AIAG: Automotive Industry Action Group
ATA: Air Transport Association
DOD: U.S. Department of Defense
EIA: Electronics Industry Association
IES: International Electrotechnical Commission
ISO: International Organization for Standardization
NASA: National Aeronautics and Space Administration
SAE: Society of Automotive Engineers
SEMI: Semiconductor Equipment Manufacturers Institute

Figure 4: Sampling of Data Matrix standards

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Most of these standards describe item (e.g. part, product, component) marking requirements, but can vary significantly by the amount and type of information to include in the Data Matrix symbol and how it should be applied and formatted. For example, just within the SEMI series, the standard for back-surface wafer marking lets users encode between seven and 18 characters of their own choosing and permits optional text marking. In the wafer-box label standard, text is required and the Data Matrix symbol is optional. The lead-frame strip standard requires 22 characters to be encoded and allows up to 50 additional characters, and has an optional 12- to 16-character provision for items not large enough to mark with the 22-character code.

The U.S. Defense Department's Unique Identification (UID) program provides a good example of Data Matrix capabilities. The term UID is used to refer both to a Data Matrix marking standard and the DoD program. The DoD has made it mandatory for contractors to provide a permanent Data Matrix UID mark on nearly all items supplied to the DoD. The UID needs to remain affixed and readable for the life of the part, regardless of how long that may be. The DoD reports the average UID Data Matrix symbol is a half-inch square, although much smaller symbols are possible. Guidelines for what needs to be marked, required data content and other information are available at www.acq.osd.mil/dpap/UID/index.htm.

The UID uniquely identifies each item (comparable to the singular identification provided by a driver's license) and will provide visibility across various DoD information systems. The military will read UID marks for asset management, inventory control, to access maintenance information and for other activities. Maintenance workers, for example, benefit from UID-marked parts by having an accurate link to all the information they need to check repair records, service histories or order replacements.

The automotive industry also uses Data Matrix. AIAG B4 is a voluntary parts marking standard that specifies the use of Data Matrix for direct part marking throughout the automotive supply chain. The goal is to facilitate parts visibility. Imagine if quality control testing at an automotive supplier reveals a defect with manufactured components. Using serialized part numbers from the QC sample, the manufacturer's production control and materials management applications should be able to pinpoint which production batches were affected. The manufacturer could then issue a targeted recall. By capturing the unique component serial number in their own production processes, downstream suppliers who assemble the components could quickly determine which of their products need to be recalled or reworked. This scenario would prevent errors and production problems, help avoid a more costly general recall, and enable all parties to deal with the problem proactively.

Data Matrix is used in other industries as well. In the commercial aviation industry, Data Matrix based systems help detect counterfeit parts. This is a leading goal of the Air Transport Association's SPEC 2000 program, which established Data Matrix as the standard for parts traceability. In the consumer products industry, Data Matrix symbols are commonly found on many products you buy at the drug store. Manufacturers use small, unobtrusive Data Matrix symbols to aid product authentication or to provide post-manufacturing lot control data.

The sheer number and diversity of objects marked with Data Matrix is a testament to the symbology's security, flexibility and value for item management, as well as its ability to help provide additional control in record-keeping applications. With Data Matrix, the ability to meet identification challenges is determined less by symbol size, and much more by the creativity and innovation of those in its ever-growing community of users.

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