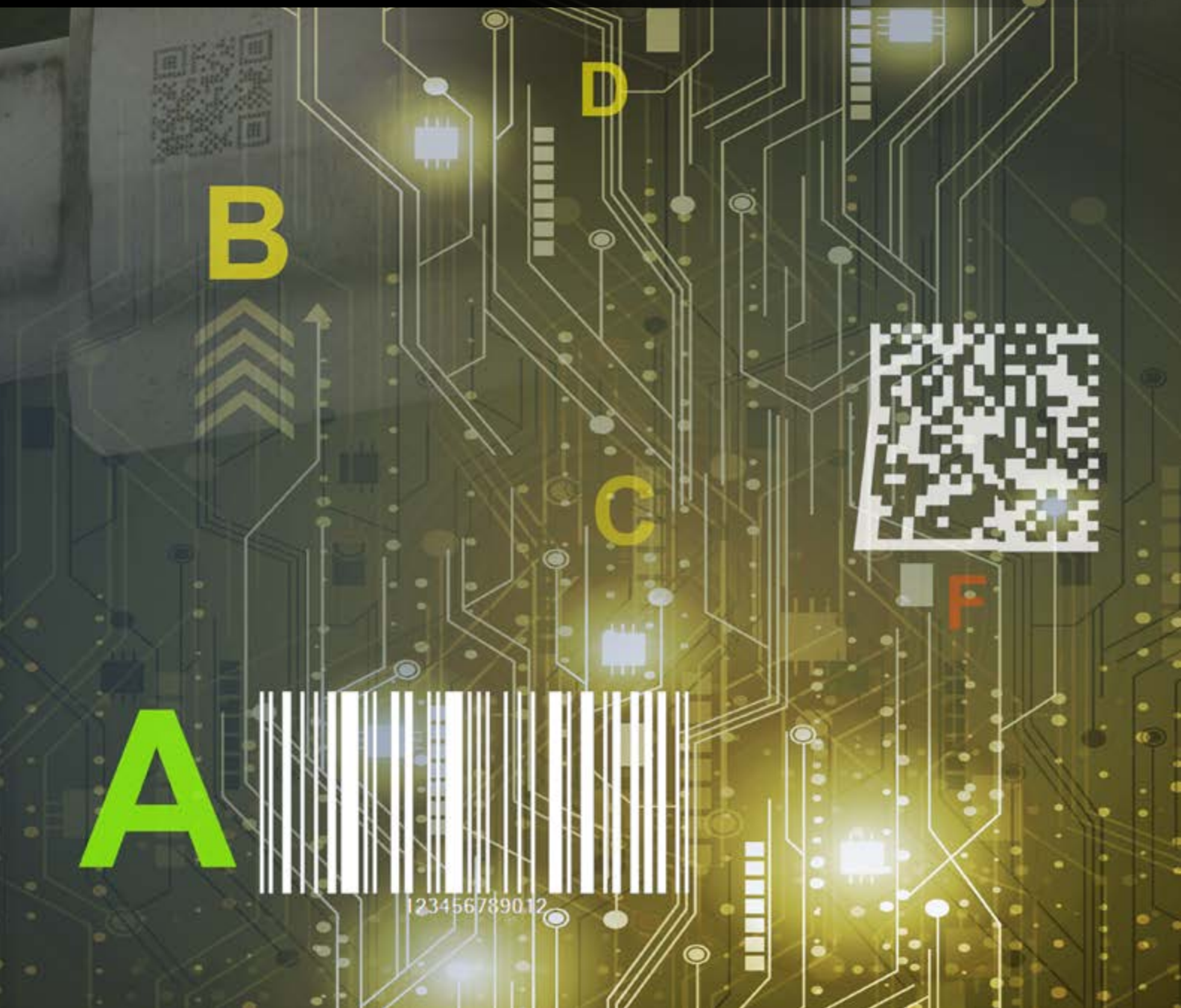
COGNEX

INTRODUCTION TO BARCODE VERIFICATION

Improve code quality to meet industry and application standards



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INTRODUCTION TO BARCODE VERIFICATION

IMPROVE CODE QUALITY TO MEET INDUSTRY AND APPLICATION STANDARDS

By Naomi Brown, Cognex Corporation

From brand owners and manufacturers to packagers and retailers, people across industries use barcodes to track their products from production to the point of sale. A failure to scan can be catastrophic, slowing down production lines and causing costly reprints, wasted product, and chargebacks.

So how can barcode producers ensure their codes are readable? Where can they look for guidance to adjust their marking processes, and how can they certify their codes meet industry requirements?

Barcode verifiers guide producers through the marking process to create codes which meet required quality standards and demonstrate compliance with printed quality reports.

This guide provides an introduction to barcode verification standards and code quality process control. It is designed to help symbol producers determine whether verification is right for them and identify their specific verifier needs.

Do I Need Barcode Verification?

The answer may be ‘yes’ if you:

- Generate barcodes in a regulated industry such as medical devices, pharmaceuticals, automotive, aerospace, packaging, retail, and printing.
- Generate barcodes in an “open system” that is highly controlled.
- Need to produce reports confirming the quality of barcodes.
- Are a quality assurance manager, engineer, or line technician.

BARCODE VERIFICATION BASICS

Barcode verification is the process of grading the quality of barcodes. A barcode verifier assigns an overall grade to a code based on measurements of several quality parameters. These parameters measure a number of factors that affect barcode readers' abilities to identify and decode a code. Verifiers test different parameters for 1D, 2D, and DPM codes based on a governing standard, such as an ISO international standard.

Is My 'Verifier' a Verifier?

Five key questions help ascertain whether a device being sold as a verifier meets the technical definition:

1. Is there an accompanying calibration procedure/routine built into the device?
2. Does it have the precise illumination positions laid out in the ISO 29158 (AIM DPM), ISO 15415, or ISO 15416 standards?
3. Does it generate a report that qualifies codes with a grade and optical arrangement (including lighting angle, light wavelength, and aperture size)?
4. Does it validate that the data within the code is formatted correctly?
5. Does it produce repeatable results?

THE NEED FOR VERIFICATION

Verification reduces product returns, packaging waste, and other expenses. The cost of reprinting and then reshipping corrected batches can be expensive. Verification alerts code producers to printing issues early in production. By monitoring verification results, printers can pinpoint a code's problem areas when quality starts to decline and take corrective action right away.

As well as helping to improve code quality, a verifier generates reports to certify the quality of a producer's codes. This is why an increasing number of regulated industries require manufacturers to use barcode verifiers. Reports can be printed or exported to a storage archive to prove compliance with contract and industry requirements.

Most verification software will also check that the data within the barcode is formatted according to the application standard for a specific industry.

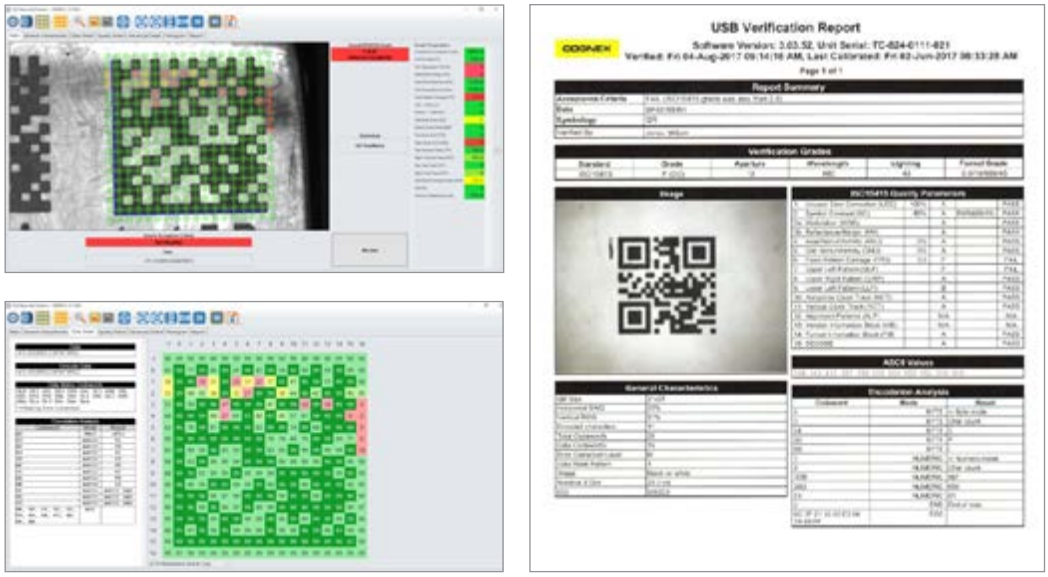


Figure 1. *Barcode verifiers calculate an overall grade based on several quality parameters, such as symbol contrast, modulation, fixed pattern damage, and grid non-uniformity. Detailed results show whether codes meet industry standards. Reports can be used to demonstrate compliance, as well as help pinpoint printing and process control issues.*

Figure 2. *Direct part mark (DPM) codes are commonly used in many industries which mandate verification.*

CODE QUALITY: BEYOND PROCESS CONTROL AND DATA VALIDATION

Many producers already monitor the quality of their codes using process control metrics (PCM) and validate their data using software on their barcode readers. Though a step in the right direction, this is not true verification and can leave producers unprotected down the supply chain. Validation looks only at the format of the data within a code and does not check print quality. And while PCM tests the same quality parameters as verification, results are unique to a reader's particular set-up, including lighting. Process control metrics by their nature are often tuned to a particular process, and some parameters may be omitted or modified since there is no standard. A verifier checks all quality parameters, uses a specific lighting set-up, and requires regular calibration.

For producers using PCM or validation whose codes are still sometimes unreadable down the line, a verifier can provide additional protection and reassurance. Manufacturers producing products for the defense, pharmaceutical, or medical device industries may be required by law to verify codes with a true barcode verifier.

Data Validation	Process Control	Verification
▪ Checks encoded data to a specified formatting standard ▪ Is concerned with only the data within the code…. ▪ …not the quality of the mark	▪ In-line control of code quality ▪ Grades the same set of parameters as a verifier but sacrifices calibration and lighting positions	▪ Contract compliant grading to a global standard ▪ Requires calibration and accurate positioning of lighting elements
When used		
▪ Required data formatting standards check (e.g. MIL-STD-130, GS1)	▪ Control the marking process with early warnings ▪ Ensure downstream readability ▪ Facilitate optimized reader setup	▪ When required or mandated by law ▪ Provide diagnostics when PCM 'flags' a code ▪ When needed to facilitate communication with trading partners

Figure 3. *A process control-based approach to code quality suits several application needs. However, when a verifier is required by regulation (e.g. UDI, UID) or mandated by the customer, a process control approach is not suitable.*

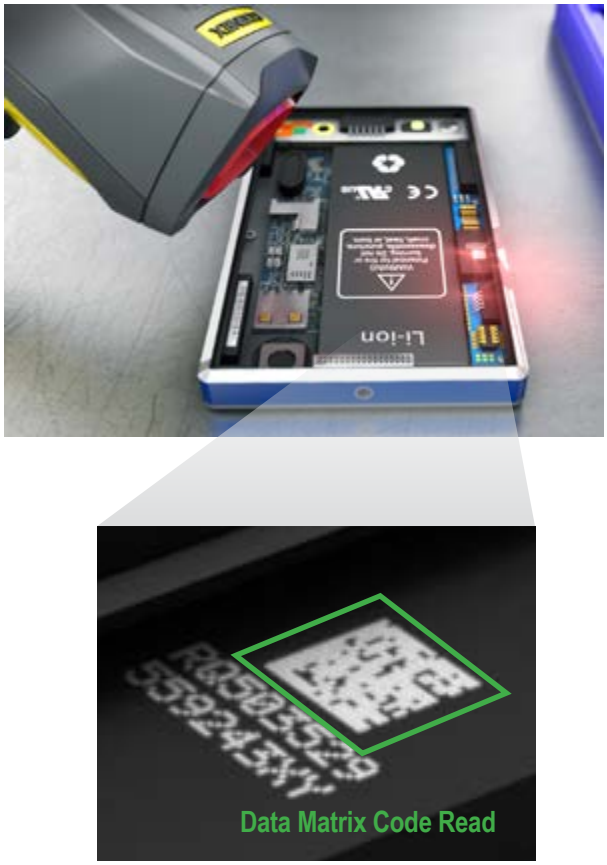
DIFFERENCES BETWEEN BARCODE READERS AND VERIFIERS

Barcode readers are designed to read barcodes and may, depending on their software, provide print quality metrics useful for process control and improvement. These metrics help producers print codes that meet their unique print quality needs and anticipate whether a generic reader will be able to successfully read their codes. Along the supply chain, a single symbol may encounter various types of barcode readers. In fact, many barcode readers include decoding algorithms designed specifically to read deformed, challenging, and hard-to-read codes. None work in quite the same way, and two readers may handle the same symbol with radically different degrees of success. Neither quality control testing nor a scanner's process control metrics can reliably gauge how two different barcode readers will handle the same code.

Barcode verifiers, by contrast, ensure codes are marked correctly and meet an industry's—rather than an individual producer's—quality threshold. Barcode verifiers are a superior measure of symbol readability because they normalize the range of performance among various types of readers, from camera and laser to handheld and fixed mount.

It is important to keep in mind that the verification process is very different from simply reading a code. A verifier takes more time to analyze a code and generates more data than a reader, which only reveals the data within a code. Barcodes which receive "passing" grades are considered to meet the minimum accepted threshold for performance and first-pass read rates. To keep pace with production, most producers will only verify a small sample of codes in any batch or run off-line. The sampling standard is determined by producers' quality control statistical requirements.

Barcode Reader



Barcode Verifier

Figure 4. *Barcode readers are designed to reveal and read the data within a code. Some barcode reader software may provide print quality metrics useful for process control. Barcode verifiers, by contrast, grade codes according to international standards and generate printed reports to help demonstrate compliance.*

CHOOSING A VERIFIER SOLUTION

Code type, code size, and substrate influence a user's specific verification needs. Four simple questions can help define what to look for when purchasing a verifier.

What is the code size?

Consider the size of the narrowest bar or smallest module printed (normally expressed in mils, or .001 of an inch). To determine required camera resolution, look for a verifier with a minimum x-dimension smaller or equal to the smallest bar width or module.

The total width of the largest barcode printed will determine the required field of view. A verifier's field of view must be large enough to show the entire code including its quiet zone (space surrounding the outside of the code).

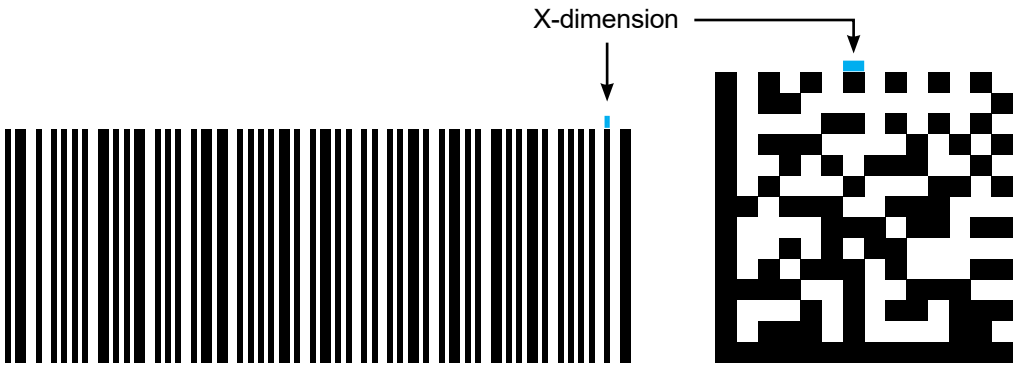


Figure 5. *A code's minimum x-dimension dictates camera resolution.*

What are the codes printed on?

Codes appear differently to a barcode reader's camera depending on their substrate. To achieve proper illumination for some surfaces, specific lighting angles are required. Most verification standards specify 45° lighting for codes printed on labels. This ensures that some light reflects off of the label and goes back to the camera. For direct part marks on a shiny, textured, or curved surface, a verifier with 30° and 90° or dome lighting option is necessary.

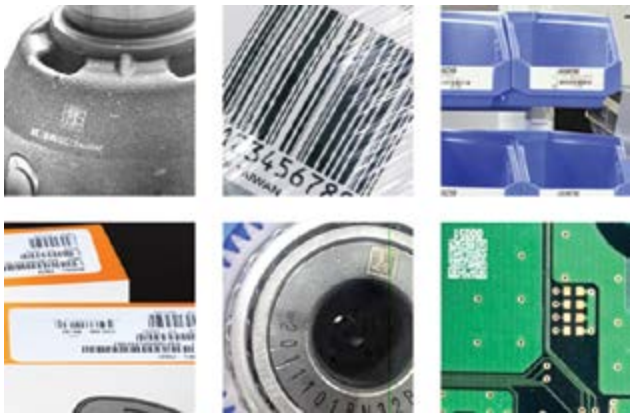


Figure 6. *Code substrates affect reflectance differently and influence lighting angles.*

Are there oddly shaped parts?

Verifiers with adjustable height stands make it much easier to position codes on small, oddly shaped parts underneath the camera. When dealing with symbols on recessed areas of a part, a verifier's software should be able to select specific regions and tell the camera exactly where to analyze a code.

What are the required software features?

A barcode verifier's software should be able to grade and diagnose issues within the barcode printing process. Consider whether it generates reports; has an easy-to-use interface; grades against GS1, HIBCC, and DOD application standards; and shows data formatting errors.

ISO INDUSTRY STANDARDS

While many parameters like bar width, height, and quiet zone are used to specify symbols' dimensional accuracy, other qualities—such as contrast and reflectance—affect the optics of barcode readers and how they "see" a code. Barcode verifiers and software report on code quality parameters and validate data for conformance to ISO/IEC 15415, ISO/IEC 15416, and AIM DPM (ISO/IEC TR 29158) guidelines.

Three major verification standards govern 1D, 2D, and direct part-mark codes.

- 1D barcodes use ISO 15416.
- 2D barcodes printed on a label use ISO 15415.
- 2D DPM barcodes use ISO/IEC TR 29158, also known as AIM DPM.

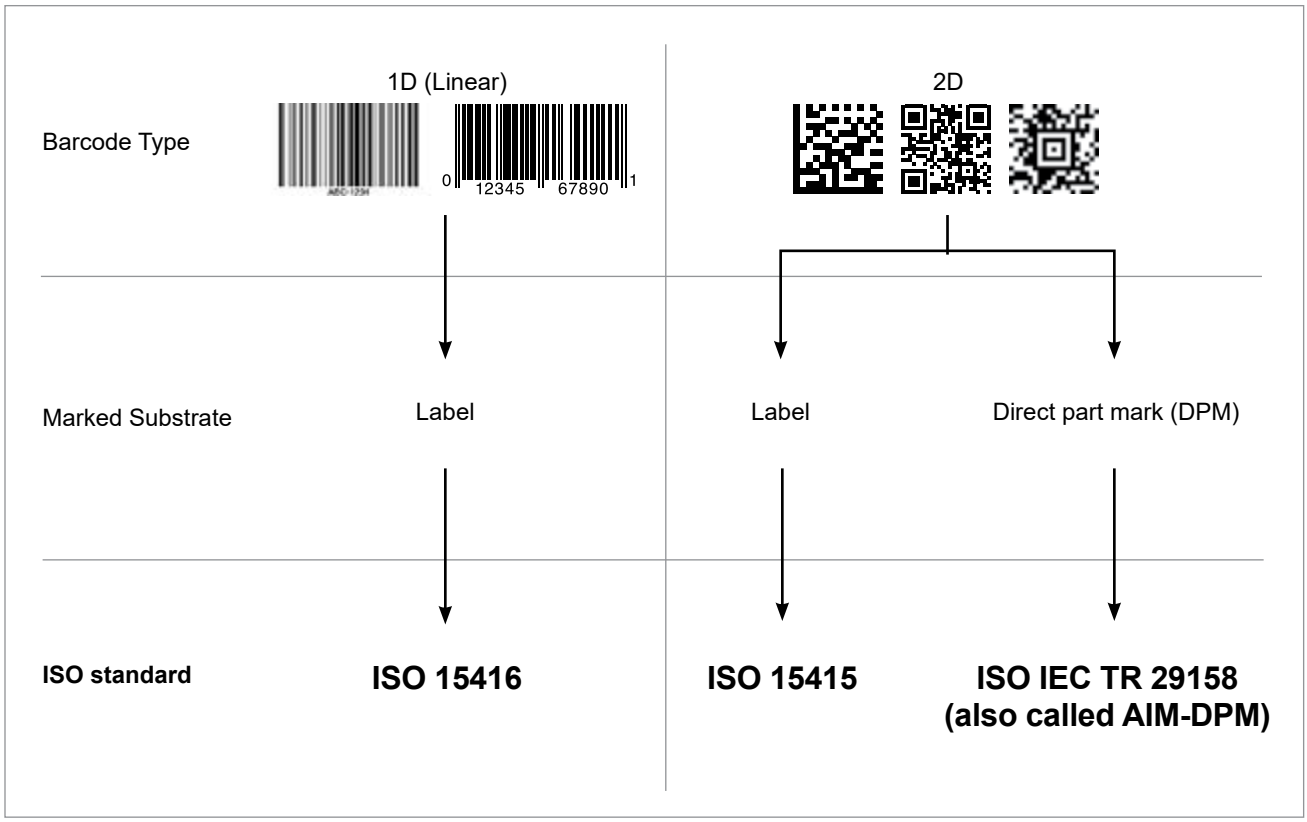


Figure 7. *Three ISO standards determine most of barcode quality.*

ISO/IEC 15416

The 1D ISO standard requires 10 individual scan lines be taken throughout the height of a code and a grade assigned to each scan line. Scan line grades are determined by many different parameters. If a scan line fails minimum reflectance, decode, or minimum edge contrast, the line automatically receives an “F” grade. If all three pass, the software grades symbol contrast, modulation, defects, and decodability parameters. Each are graded on a scale of A to F. Once every scan line has been graded, the 10 scans are averaged to generate a formal grade for the barcode.

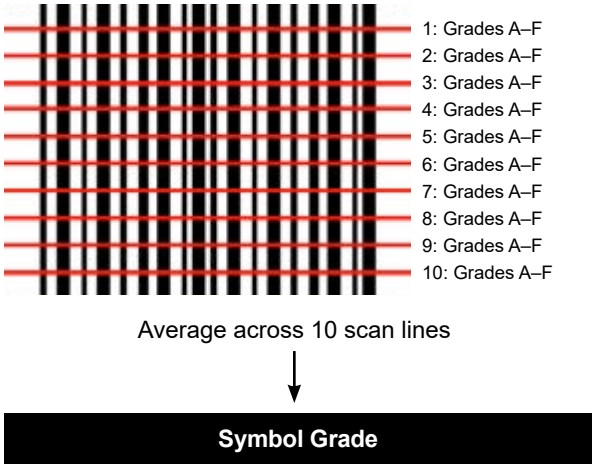


Figure 8. *Take 10 scan lines along the length of the code, grade each scan line, and take the average for the overall grade.*

Minimum Reflectance checks whether the bars are dark enough to meet the required ratio of light that is reflected off of the spaces.

Bars too light

Edge Contrast measures the difference between adjacent bars and spaces.

Background too dark

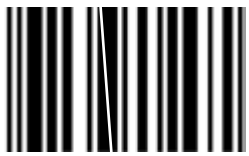
Modulation refers to local variations in contrast.

Localized contrast

Decode checks to see whether the code can be read using the standard reference decode algorithm.

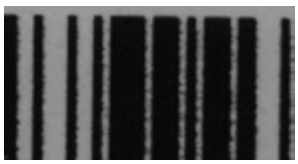
Symbol read? Y/N

Defects include printing errors, dirt, or markings that affect one single bar or space.



Irregularities

Decodability grades the accuracy of bar and space widths compared to their ideal size. A barcode with bar width growth or distortion will score a low decodability grade.



Bar Width Growth/ Loss or Distortion

Figure 9. *Quality parameters for 1D codes include minimum reflectance, edge contrast, modulation, decode, defects, and decodability.*

ISO/IEC 15415

2D barcodes are graded against 8 different parameters. The lowest individual grade becomes the overall grade for the code. The grading process begins with a pass/fail test. If the code can be decoded, it passes the first test. If it cannot, it is automatically assigned an “F” grade. After a code is decoded, it is graded for symbol contrast, modulation, reflectance margin, fixed pattern damage, axial non-uniformity, grid non-uniformity, and unused error correction.

Symbol Contrast refers to the difference between the darkest and the lightest modules.

Modulation measures local variations in contrast.

Fixed Pattern Damage includes errors with the L sides or clock pattern or quiet zone.

Axial Non-uniformity refers to the uneven scaling of the code.

Grid Non-uniformity measures the biggest deviation from the grid.

Figure 10. *Quality parameters for 2D codes include symbol contrast, modulation, fixed pattern damage, and axial and grid non-uniformity.*

ISO/IEC TR 29158 (AIM DPM)

The quality parameters and grading process for DPM codes are similar to ISO 15415, with a few key differences. The first is the way the global threshold is determined. Global threshold is essentially the dividing line between light and dark cells. Where that line is drawn is very important, since it defines whether a cell is closer to light or dark. To accommodate a variety of background surfaces, AIM DPM calculates global threshold using a more sophisticated algorithm than ISO 15415. Modulation typically improves as a result. AIM DPM also allows the use of 30°, 90°, and dome lighting in addition to 45°. This makes verification on parts that are curved, reflective, or marked using dot peen possible.

Differences between ISO/IEC 15415 and AIM DPM

- Global threshold calculation
- Modulation calculation
- Available lighting options are expanded to include 30° and 90°, in addition to 45°

APPLICATION STANDARDS

Some industry committees have developed application standards mandating that their manufacturers comply with their rules for barcode marking. An application standard outlines what type of symbology is acceptable, what ISO standard to grade against, the minimum acceptable grade, aperture, x-dimension range, lighting required, and how the data within the barcode must be formatted.

Application standard examples include:

- Unique Device Identification (UDI)
- GS1
- Unique Identifier (UID) for MIL-STD-130

Application Standards rely upon:

- ISO 15415 or ISO 15416 or AIM DPM

Application Standards dictate:

- Aperture size
- Allowed x-dimension range
- Symbologies
- Minimum passing grade
- Condition of verification, such as lighting

UDI for medical devices

The FDA has mandated that all medical devices contain a Unique Device Identifier (UDI) by the year 2020. A UDI is a barcode containing a specific set of information that the FDA has required to be on all medical devices. The ruling requires that all medical devices be labeled with a barcode graded according to GS1 or HIBCC rules and list a product's lot number, serial number, and expiration date if applicable. Additionally, the FDA requests that a portion of the information within each UDI barcode be submitted to the FDA's Global Unique Device Identifier Database (GUDID) system. The information required depends on the medical device type.

GS1 for retail POS and distribution

Barcodes in retail, transportation, and food service use a standard provided by GS1 to regulate barcode quality in their industry. Global manufacturers must register with GS1 to receive their individual GTIN number, which ensures that no two product barcodes of the same symbology contain the same data. Those manufactures must follow the data formatting stated in the GS1 standard and meet the print quality required.

UID (MIL-STD-130)

Items sold to the United States Department of Defense must use a UID marked according to MIL-STD-130, an application standard designed to help the US government track purchasing details, maintenance logs, and out-of-commission dates in a central registry. MIL-STD-130 Data Matrix codes must meet both readability (print quality) and data formatting requirements. Print quality requirements can be met through measurements in accordance with ISO 15415, AS9132, or AIM DPM. The data must be formatted in accordance with ISO 15434 using AI's, DI's or TEI's.

	Defense	Medical Devices	Retail/Pharma
Application Standard	UID	Unique Device Identification (UDI)	GS1
Symbology	DataMatrix	Linear or Data Matrix issued by GS1 or HIBCC	Linear or DataMatrix issued by GS1
Format of Data	MIL-STD-130	Device Identifier (DI) and a Production Identifier (PI)	GS1 Application Format
Cheat Sheet	▪ Starts with **[)>** ▪ Uses **<GS>** as a group separator ▪ Ends with **<EO>**	▪ DI starts with **(01)** ▪ PIs relate to batch information and usually contain **(10)** or **(17)**	▪ Starts with GS1 header **<F1>** ▪ Contains Application Identifiers for **GTIN, Lot, Batch, expiry** etc. ▪ Contains a Check Digit

Figure 11. *Application standards are industry guidelines used alongside ISO standards.*

CONFORMANCE STANDARDS AND CALIBRATION

Barcode verifiers must be calibrated to traceable standards. The calibration process adjusts the brightness of the image and therefore is not specific to the symbology. Conformance cards are a widely used industry tool designed to support proper calibration of the verifiers. Conformance Calibration cards contain symbols with intentional imperfections that are used to check the reporting capabilities of the verifier and document conformance to industry standards such as ISO/IEC 15415, ISO/IEC 15426-2, and GS1 specifications. Calibration cards expire two years from the issue date.

Figure 12. *Examples of calibration cards.*

CONCLUSION

For those printing and handling codes and for customers receiving codes, verification provides reassurance and confidence that symbols will be readable and perform in their operations. For an increasing number of regulated industries, it also ensures compliance with contract and industry requirements. Barcode verification is therefore an essential quality control tool to ensure a barcode's complete scannability along the supply chain.

THE COGNEX DIFFERENCE

Cognex offers a range of barcode verification solutions, offering the greatest versatility and the most diagnostic tools in the industry. Using proprietary high-resolution imaging and advanced algorithms for analysis, Cognex verifiers provide consistent and repeatable results that are reported clearly in accordance with industry standards. Simple software provides a detailed analysis of each module, helping users identify precise defects within codes that are causing faulty scans. As the only company that can provide verification solutions for 1D, 2D, and DPM symbols, Cognex has the right verifier for every need.

For more information on our entire product range, visit www.cognex.com.

About the author

Naomi Brown is the Product Marketing Manager for Barcode Verification Products at Cognex. She previously led Sales and Marketing for Webscan Inc., the industry leader in Barcode Verification. Webscan was acquired by Cognex in 2016.

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