axicon THE BARCODE EXPERTS

Getting it Right

1D Bar Code Quality Step By Step

Connecting the Dots from the Verification Report to Solving Your Linear Barcode Problems

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Introduction

This document discusses the print quality of 1D or linear barcodes based on ANSI/ISO specification 15416 and its predecessor known as Traditional Verification.

Traditional Verification was never a standard or a specification because traditional test methodology was never developed, as will be discussed later.

Traditional Verification is based mostly on element (bar and space) width measurement and comparison to calculated or ideal widths. ANSI/ISO specification is built almost entirely on the reflective attributes of the symbol. This is a more reliable predictor of barcode performance “in the field” because barcode scanners function based on reflectance variations. But Traditional Verification addresses some essential barcode characteristics and most verifiers will test and report attributes from both methods.

The basic building block for ANSI/ISO verification is the Scan Reflectance Profile (SRP) which is not an attribute of the grading system. The SRP is a graphical map of the reflectance properties of the barcode symbol from which almost all of the attributes of the symbol are measured and graded. Think of the SRP as the “eyeballs” that allow you to look at the barcode in terms of its reliability and likelihood of success as a data storage tool.

Unlike other barcode quality manuals, this one will not only introduce you to the 2 Traditional Verification parameters and the 9 ANSI/ISO parameters for barcode quality, it will also attempt to “connect the dots” and relate these parameters to the common print methods. If you are a flexo or a litho printer, for example, this guide will help you understand what each parameter means in terms of your process, and what to do if the barcodes you are printing don’t scan properly.

The ANSI and ISO specifications are substantially the same. The chief difference is the way grading is expressed. ANSI grading is in alphabetical letter form (A-F); ISO grading is numerical (1.0– 4.0) with decimal fractions. This allows the ISO grading system to be more precise than the ANSI system. In the ANSI system, a C grade could be a low C, almost a D, or a high C, almost a B, and you wouldn’t know it.

It is important to note that there are actually two ANSI/ISO specifications relating to linear barcodes. ANSI/ISO 15416, the “methodology” specification, relates to what attribute to grade, how to grade it and how to report it. Think of this as the “measuring stick.” ANSI/ISO 15426-1, the “conformance” specification, relates to the performance of the test device (the verifier) itself, evaluating it against a known, traceable standard to ensure that it is testing and grading the printed symbol accurately. Think of this as making sure the “measuring stick” is trustworthy.

How important is this? Skeptics claim that ANSI/ISO compliance adds needless expense to an already-expensive technology—a verifier is basically a “glorified scanner”. Why not use a non-glorified scanner at a fraction of the cost of a verifier?

A scanner cannot perform the duties of a verifier because a scanner is a go/no-go gauge. It either decodes the barcode or it doesn’t. It doesn’t tell you why or when the symbols in a print run are about to fail. Furthermore, scanners are not manufactured to a performance standard; different scanners perform differently. Some are more fault tolerant, others are more unforgiving. A verifier—even those from different manufacturers, is designed to test the barcode to a known standard. Theoretically all verifiers should grade a given barcode the same.

As the use of barcodes has expanded beyond the consumer commodity supply chain into more critical roles in food safety and pharmaceutical trace and track the importance of reliable, predictable barcode performance has increased drastically. The barcode is a vital link and failure to perform is more than an inconvenience. There is substantial potential risk and liability associated with poorly performing barcodes. Not using ANSI/ISO compliant testing tools makes no sense when there is so much riding on the quality of the barcode.

Scan Reflectance Profile

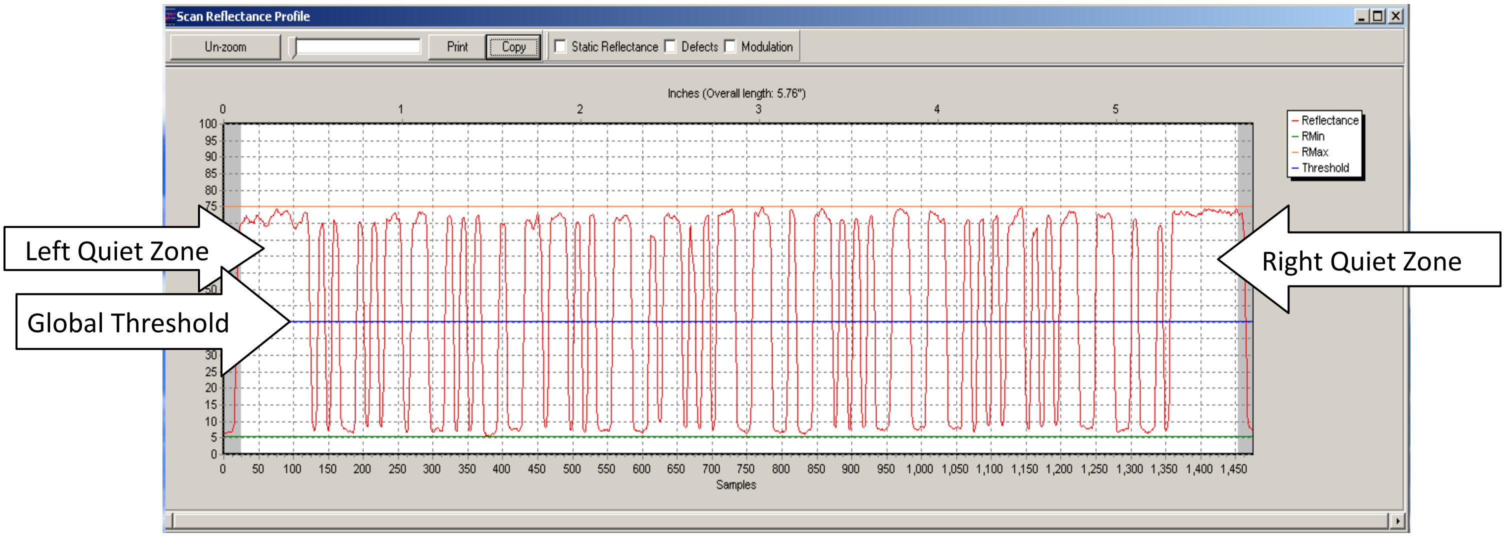
In barcoding, Reflectance is defined as the amount of red light at a wavelength of 660nm as it bounces off an object at a predictable angle.

The Scan Reflectance Profile or SRP is the foundation of ANSI/ISO verification for linear barcodes. It is a graphical representation of the light and dark reflectance values of the entire symbol, left-to-right, from the left margin (leading quiet zone) to the right margin (trailing quiet zone).

While the SRP itself is not an ANSI/ISO parameter for barcode quality, it graphically records the information for six of the 9 parameters for barcode quality, having to do with the reflective qualities of the barcode.

Because it is based on reflectivity, the ANSI/ISO method of verification is more similar to how scanners work than Traditional verification which is based on physical measurement of bar/space widths. This makes SRP-based verification more reliable as a predictor of barcode behavior at the point-of-use.

However, the SRP is not very helpful in diagnosing barcode problems and figuring out how to adjust a printing method to improve results. What is needed is to investigate each problematic parameter(s) to understand what is causing the problem.



The ANSI/ISO Parameters

Edge Determination

Edge Determination is accomplished by counting the bar-and-space transitions at the Global Threshold to determine if the symbol is a known type; a non-matching count will cause this parameter to fail.

Edge Determination is a not a measure of how well the bars and spaces can be detected. The count is either valid or not and therefore this is a pass/fail parameter.

In order to count bars and spaces, the verifier locates the Global Threshold or GT which is positioned exactly half way between the highest reflectance and lowest reflectance values on the Scan Reflectance Profile.

The Scan Reflectance Profile graphically represents the count of bar-space transitions through the GT.

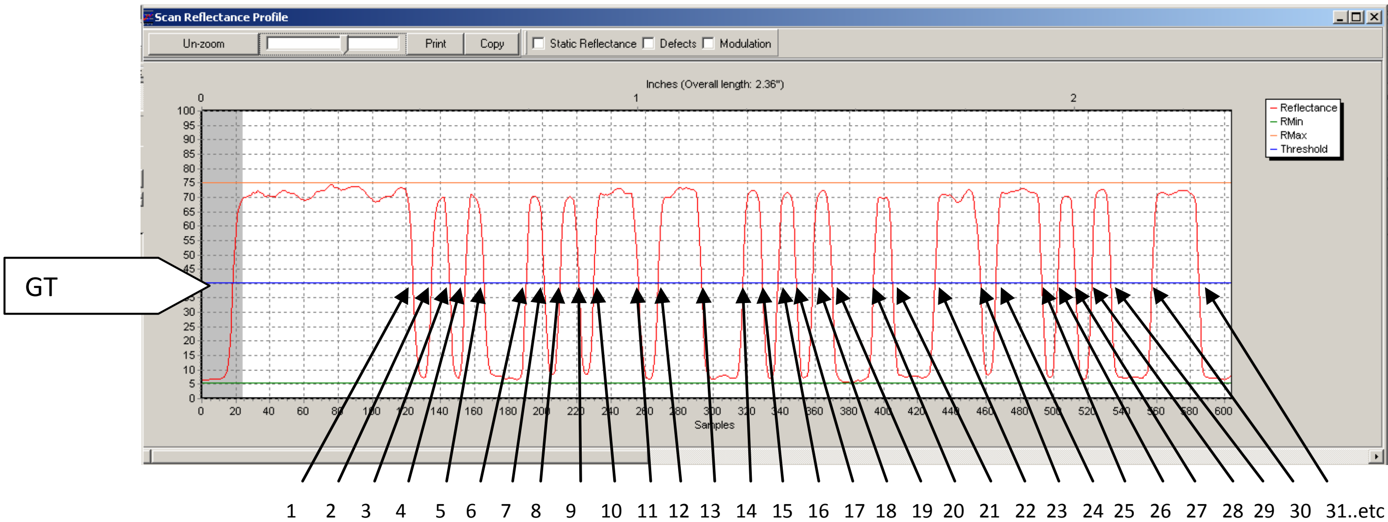
Rmin is the lowest or minimum reflectance value found in the barcode. The Rmin is found in the bar, which contains the lowest reflectivity.

Rmax is the highest or maximum reflectance value found in the barcode. Rmax is found in the space or quiet zones which reaches the highest reflectivity.

SC or Symbol Contrast is a simple subtraction of the Rmin from Rmax.

The formula for locating the Global Threshold is:

$$GT = Rmin + SC/2$$



GT = Global Threshold

Minimum Reflectance

The reflectance value for the lowest reflecting bar must be less than or equal to one half the highest reflecting space (or quiet zone) in the barcode. Thus, if the highest reflectance space or quiet zone is 75%, the Rmin of at least one space must be no more than 37.5%.

The darkest bar in the barcode contains the Rmin value and the lightest background which includes the spaces and quiet zones contains the Rmax value. Although a reversed image could theoretically produce an acceptable Minimum Reflectance, it would violate the Print Contrast Signal system for barcodes, which dictates that bars *must* be dark; quiet zones and background (spaces) *must* be light.

Since Rmin either is or isn't equal to or less than 50% of Rmax, this is a pass-fail parameter.

Obviously, if Minimum Reflectance is marginal or failing, improving it can only be accomplished by increasing the Rmax or decreasing the Rmin.

Think of this parameter as a benchmark. The lowest reflecting bar and the highest reflecting space (or quiet zone) establishes a sort of benchmark for the symbol. Within a Scan Reflectance Profile there is only one Rmax point and only one Rmin point (although there could be multiple Rmax or Rmin points with the same value)

Symbol Contrast

This one is easy—Symbol Contrast or SC is a straight subtraction of Rmin from Rmax; the higher the contrast, the better the grade. Here's how grading works:

SC = $\geq$ 70% = A

SC = $\geq$ 55% = B

SC = $\geq$ 40% = C

SC = $\geq$ 20% = D

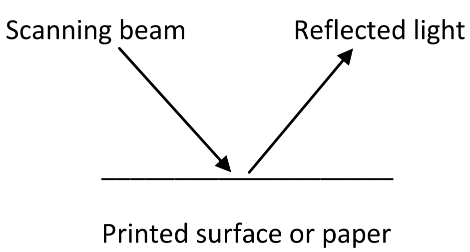
SC = < 20% = F

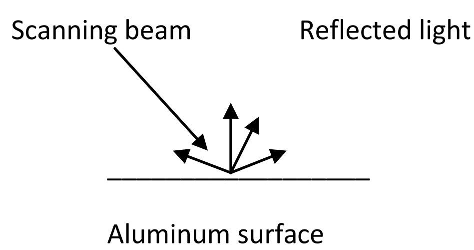
Obviously low Symbol Contrast grades can be improved either by increasing Rmax, decreasing Rmin, or both.

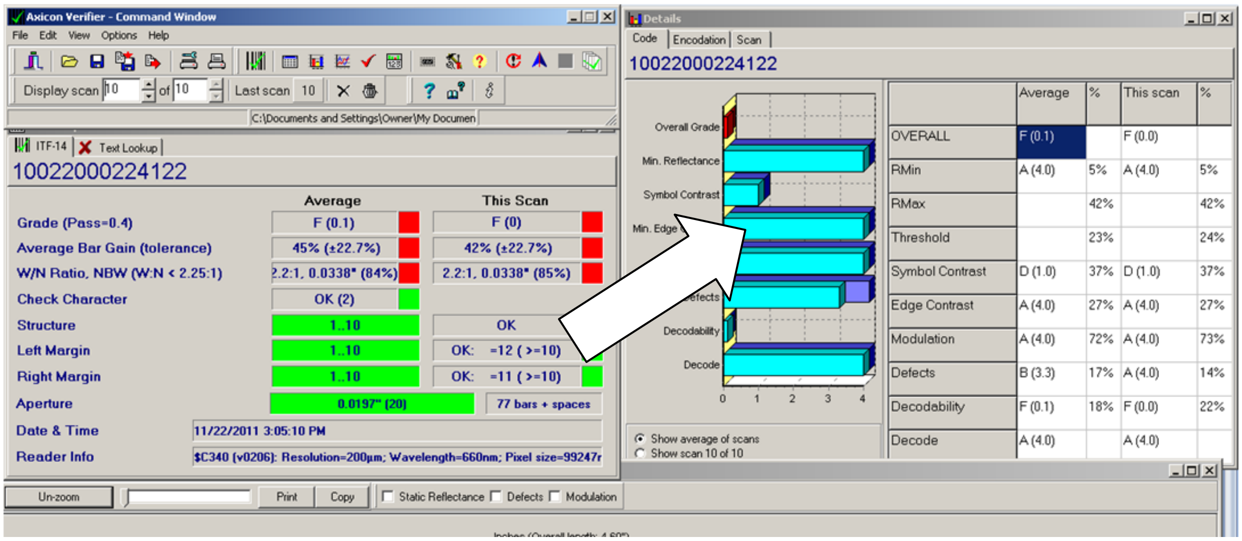
Not so obvious is the way certain substrates and certain inks behave. Bare plastic containers Fig 1 shampoo bottles may not be as reflective as one might assume.

For some soft drink cans the barcode is reverse printed—the spaces are printed and the bars remain, represented by the bare aluminum surface.

With two-piece aluminum cans the <u>spaces</u> are printed white or a light color and the <u>bars</u> are often left as the bare aluminum substrate. This metal surface is specularly (mirror like) reflective so that at almost every orientation the scanning beam is reflected away from the scanner. Thus these shiny bars appear black to the scammer. The printed white spaces are diffusely reflective so that a portion of the reflected light is returned to the scanner as it would be from a paper or plastic surface. See diagram below:







Symbol Contrast problems are common in printing barcodes on corrugated because the Rmax of the bare kraft substrate is usually so low, the Rmin cannot be low enough to create enough difference to achieve a grade higher than a D. The solution would be to print a white patch or knock-out over the bare kraft and print a black barcode in a second pass.

Symbol Contrast is not an unknown problem in other printing methods, but those situations are usually caused by ill-advised bar and space color combinations or highly reflective bar colors on highly reflective space substrates. This is common in flexo printing and metal decorating.

Modulation

Scanners decode barcodes based on the reflective differences between bars and spaces. Laser scanners decode with a timing algorithm by keeping track of the number of microseconds between each bar/space boundary. Engineers refer to these time intervals as "measurements".

In an ideal world, the low reflectivity of a narrow bar and a wide bar would be about the same, and the high reflectivity of a narrow space and a wide space would likewise be about the same. But even when the barcode is perfectly printed, there can be significant differences in the reflectivity of narrow and wide elements. Modulation measures the variation in signal strength within a scan reflectance profile. Specifically, Modulation is ECmin divided by Symbol Contrast (SC).

Here's the formula: Modulation = ECmin/SC

ECmin is Edge Contrast Minimum
SC is Symbol Contrast
Here’s how the grading works:

Modulation = $\geq$ 70% = A

Modulation = $\geq$ 60% = B

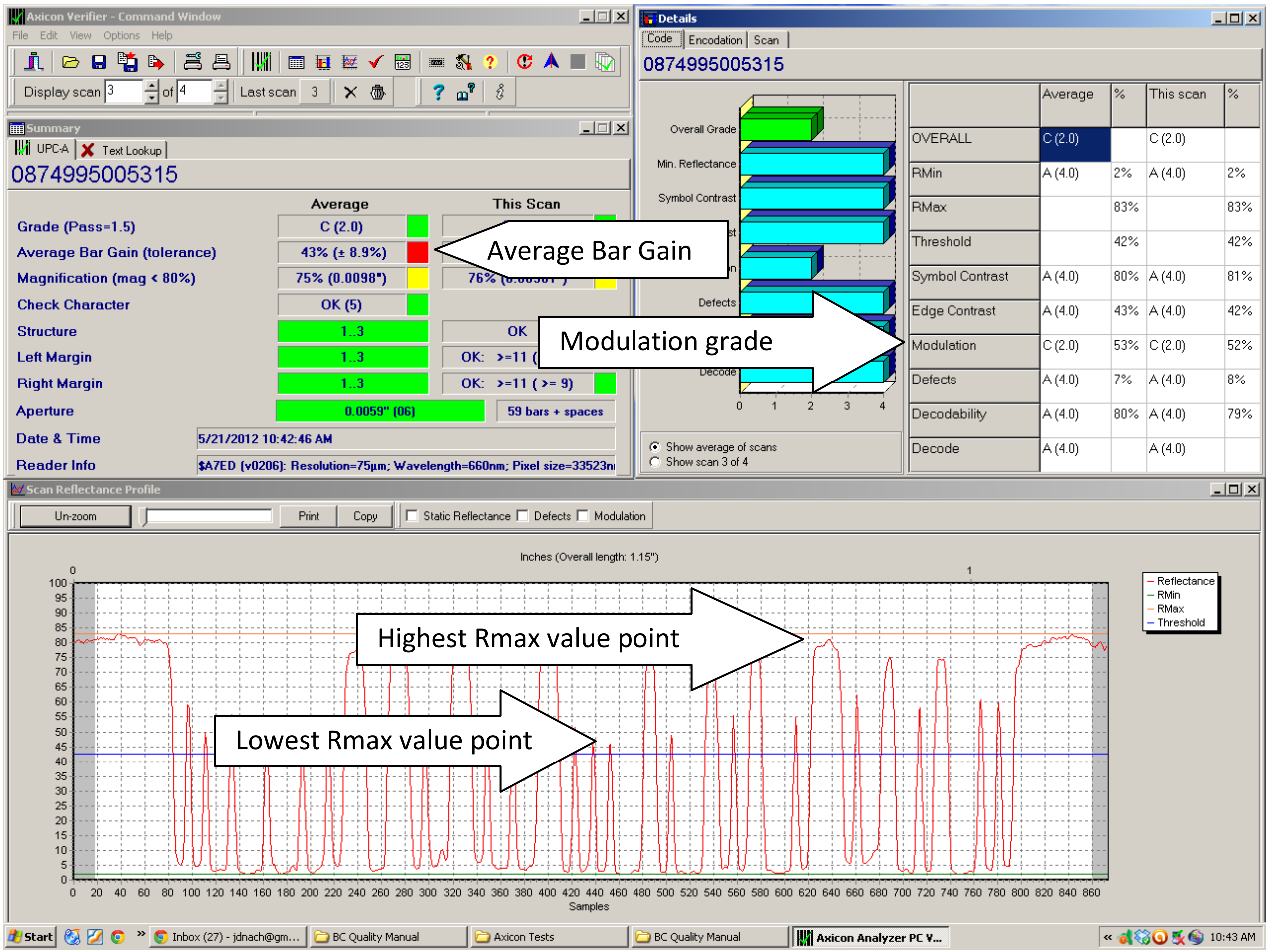
Modulation = $\geq$ 50% = C

Modulation = $\geq$ 40% = D

Modulation = < 40% = F

Modulation deteriorates when the bars experience press gain. Narrow spaces in particular will lose reflectivity. If the reflectivity of the narrow spaces is degraded to the point where they begin to fail to cross the Global Threshold on the Scan Reflectance Profile, Edge Determination will be incorrect, and the scanner will begin to fail to decode the symbol.

The verification report below pertains to the poorly printed symbol above.



Ideally these two values would be the same—but they are obviously not the same. The difference between these two points is Modulation

Here the C grade for Modulation grade isn't that bad, but at ISO 2.0, it is barely above a D grade. The SRP shows very clearly the differences in the reflectance values of wide spaces in comparison to narrow spaces. Excessive ink spread is the cause—notice the Average Bar Gain of 43% in the Summary window (upper left).

Modulation problems are not uncommon to all printing methods. This example is from a thermally printed label but modulation problems are seen in flexo printing and litho printing too.

Modulation measures the smallest signal swing between a narrow space and an adjacent bar. Defects measures the amplitude of a double peak or bottom within a single bar or space.

Defects

As the name implies, Defects are artifacts in the spaces or gaps or voids in the bars. The technical term for such an undesired feature is an Element Reflectance Non-uniformity or ERN. Remember, ANSI/ISO verification is all based on reflectance, so a defect is something that causes a non-uniformity in the reflectance value of a bar or space (element).

A defect can be caused when ink does not cling uniformly to the substrate. Ink spatter or a dirty printing environment may cause unwanted spots or artifacts in the spaces or quiet zones.

The smaller the amount of non-uniformity, the higher the grade for the Defects parameter.

The parameter Defects is graded as follows:

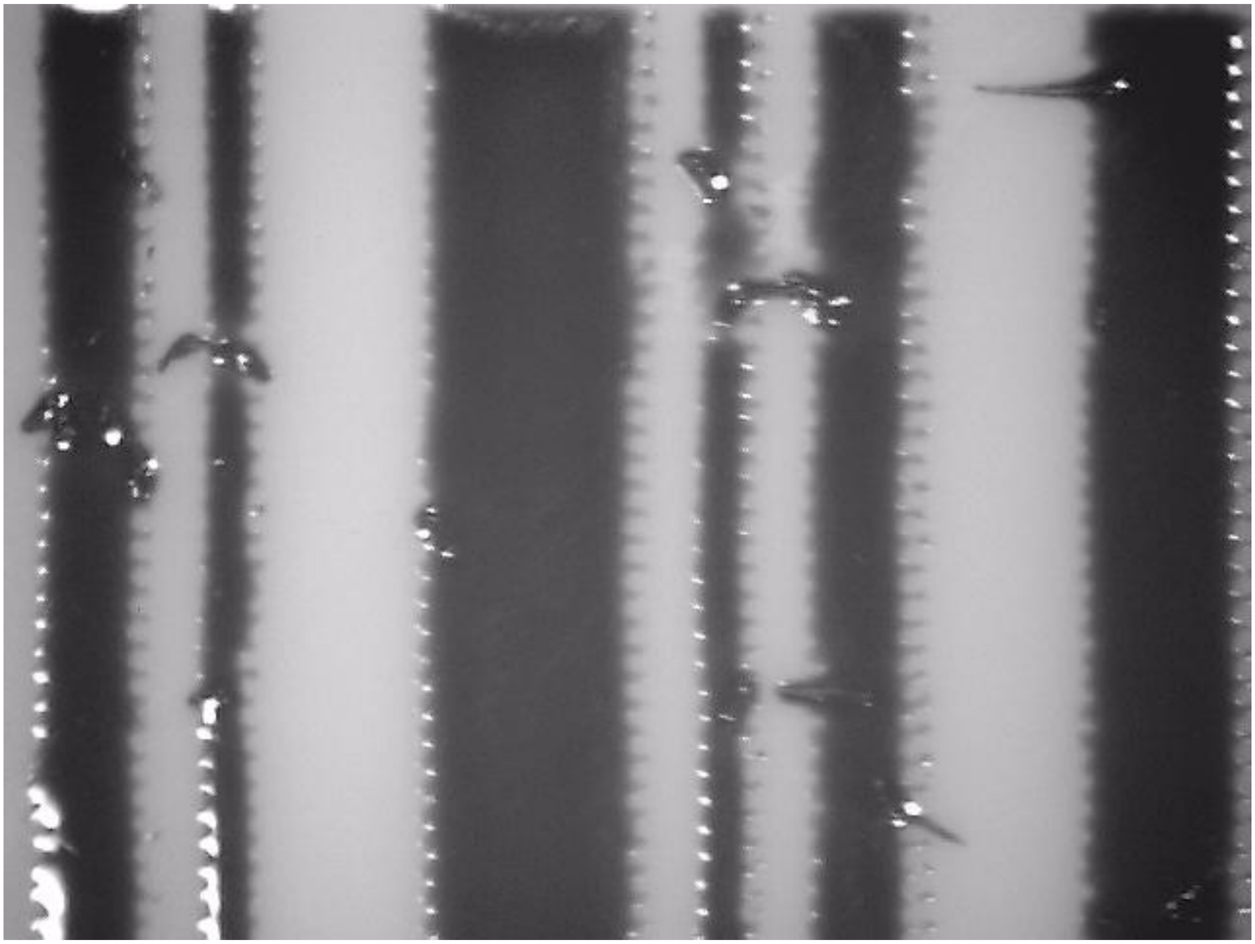
Defects = ≤ 15% = A

Defects = ≤ 20% = B

Defects = ≤ 25% = C

Defects = ≤ 30% = D

Defects = > 30% = F



Decodability

Decodability is a complicated, non-intuitive parameter.

It is briefly defined as the amount of tolerance remaining for the scanner, after the printing process.

Decodability problems are not always obvious to a visual inspection of the barcode. Therefore it is not apparent how to adjust the printing process to improve a low decodability grade.

Decodability is a graded parameter which is calculated based on the engineering specification for the symbology, so decodability grading varies depending on the symbol type.

For example, some symbologies have only two element widths, others have several. The encoded characters in some symbologies are self-contained and separated from each other by a fixed-width space, others are separated by a variable gap or space which is part of the encodation scheme. Different symbol types have different start/stop patterns.

The decoding formula can be written to accommodate various amounts of inaccuracy in the printed image. This is why decodability varies between various symbol types.

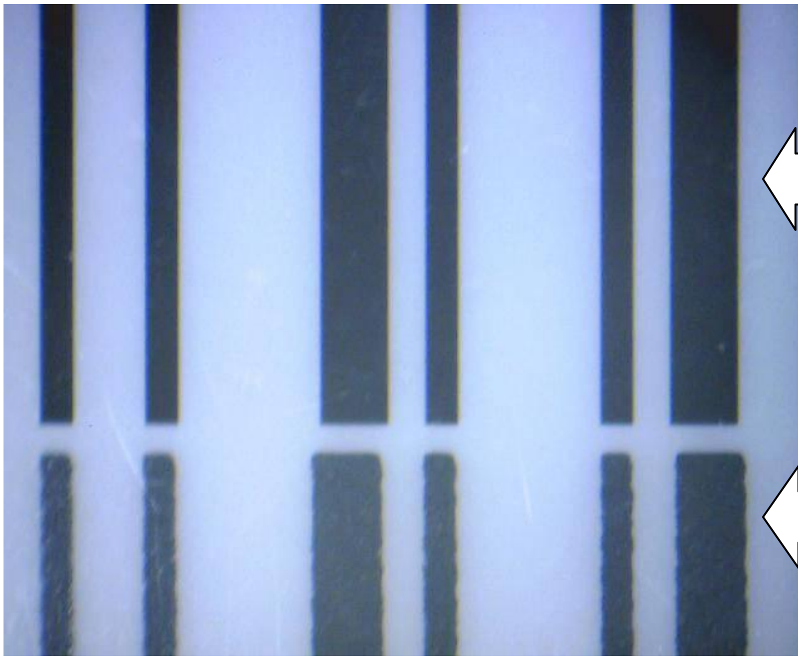
A low decodability grade is often—but not always—accompanied by a low grade on other parameters including Modulation. Excessive ink spread is a common cause of a low decodability grade.

Consider a thermally printed UPC symbol where the printer has a resolution of 203 dots-per-inch and the narrow bars and spaces are nominally 0.00985”. If the ink spread (in this case heat spread) is 30% of the specified narrow bar, the decodability would be reduced to a D grade.

Low decodability can also be caused by mismatched computer design file and printer resolution. Users have the opportunity to define the resolution of the barcode in the barcode design software. Usually this is done in DPI (dots per inch) but sometimes it is described in different units of measure. The printing device will also have its own resolution, and sometimes in a different unit of measure. The potential problem is when the resolution of the design file and the resolution of the printing device do not match mathematically.

Imagine that the digital design information that is being sent to the printer is asking for 400 DPI but the printer can only resolve 203 DPI (this is a common resolution for many thermal and thermal transfer printers).

The printer attempts to do what the digital information is demanding by “pixel rounding”, slightly modifying the widths of bars or spaces, or relocating them to slightly different positions in relationship to each other. The printer does this because it can only resolve the digital information to its native DPI and not to some fraction of a pixel since there is no such thing as a portion of a pixel.

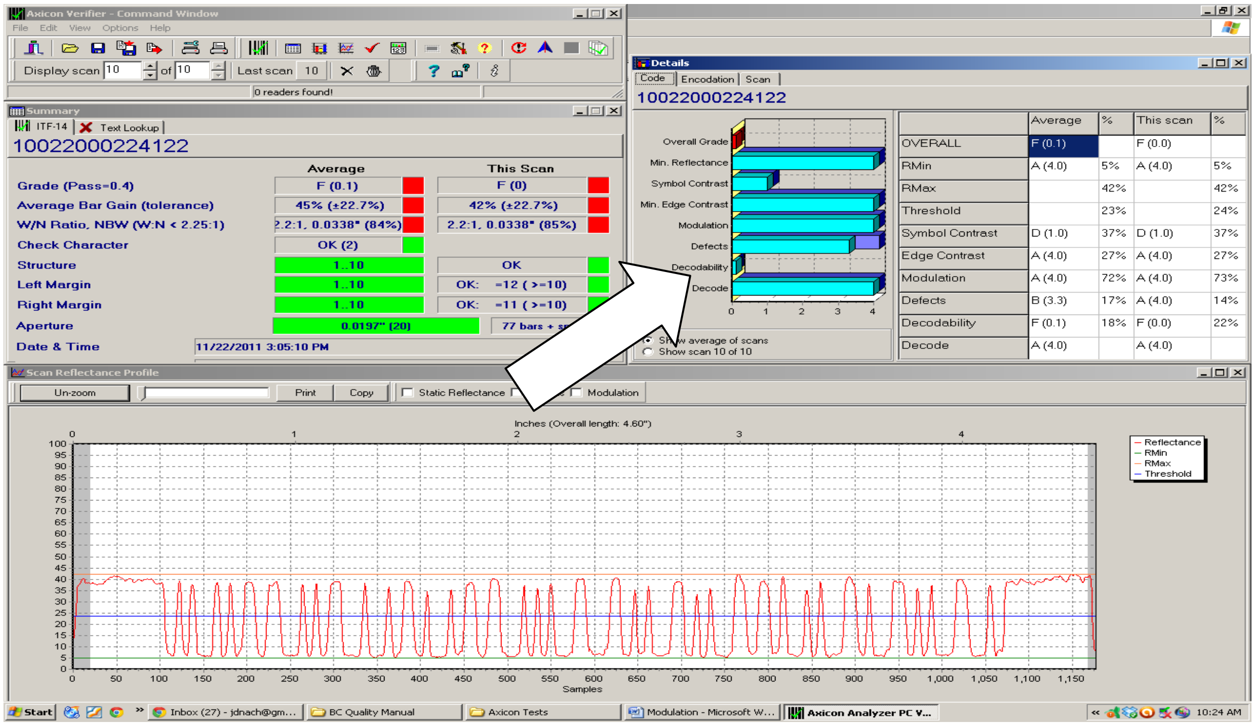


Top image is a high resolution “perfect” image of bar and space widths and locations

Bottom image is a micro-photograph of the actual barcode. Notice how bar widths and locations have been changed

Pixel rounding wreaks havoc to the integrity of the barcode image and triggers the parameter Decodability. The barcode looks fine visually and the bars may not exhibit any excessive bar width gain and no other parameters may be signaling problems.

The only way to conclusively identify the source of the problem is to obtain accurate information about how the barcode was designed, or to physically measure the barcode with a microscope.



Decode

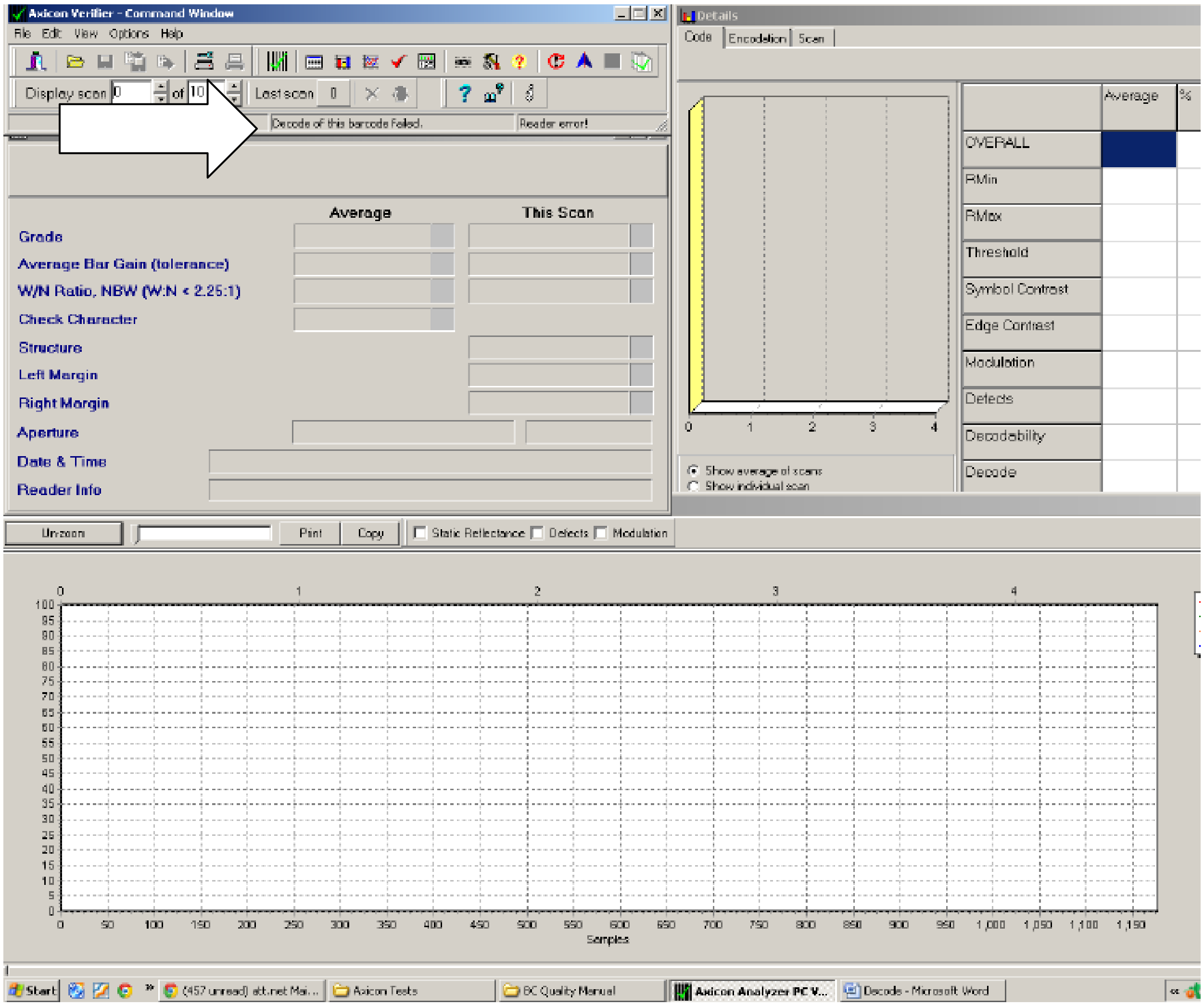
When the scanner detects a pattern of bars and spaces known to represent a set or series of characters that are consistent with the specifications for a valid symbology, the parameter Decode passes. This either happens or doesn't; Decode is a pass or fail parameter.

In determining Decode, the global threshold (GT) is <u>only</u> used to establish a valid count of bars and spaces for the symbology being decoded. The actual decode process derives its measurements not from intersections with the GT but according to the Edge Determination process. Decode is accomplished (or not) by virtue of the count and positions of transitions of various widths from light to dark reflectance values across the symbol.

If the barcode cannot be decoded, no graphic representation of the barcode is shown.

The decode error is usually indicated as an error message in the verification report.

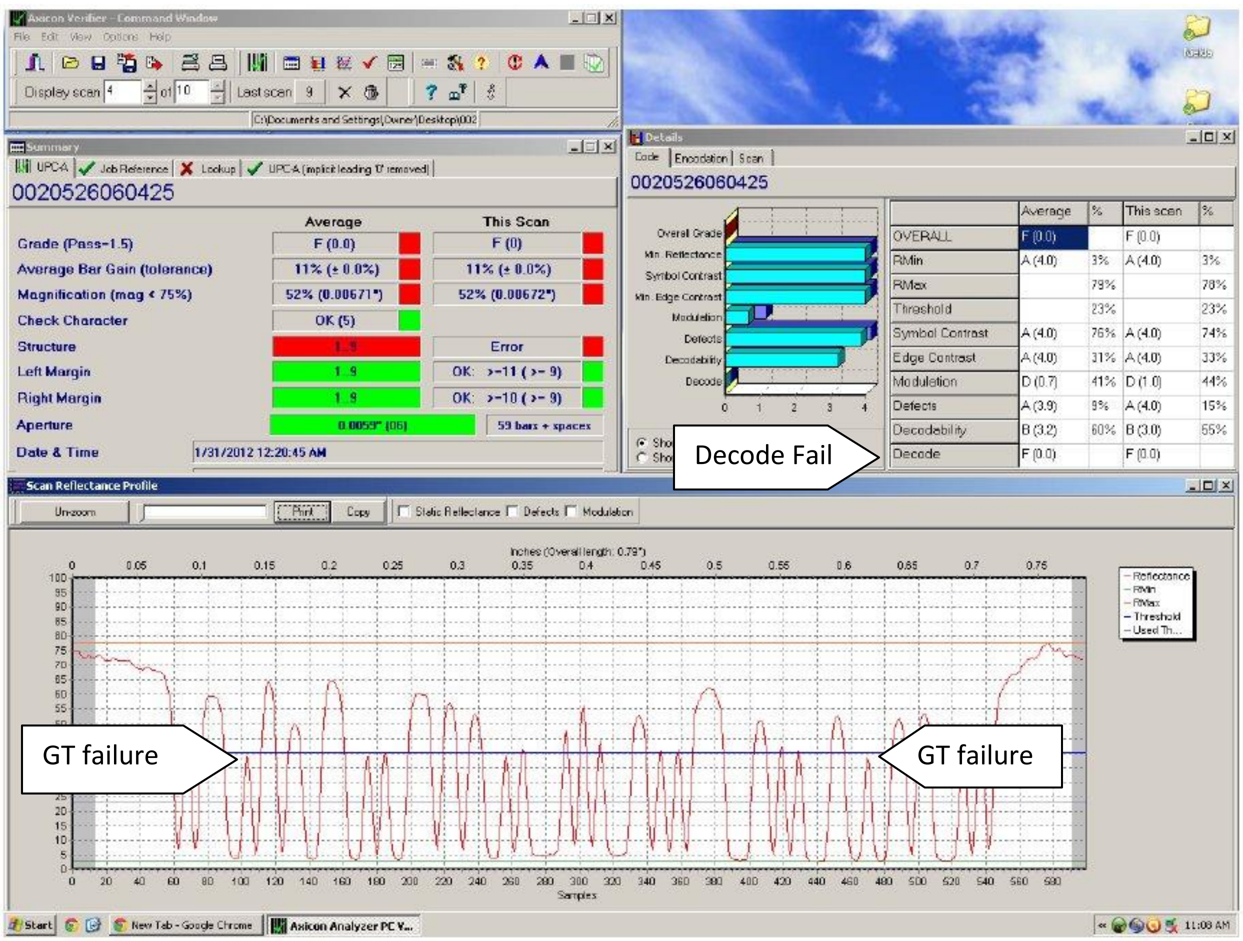
Because the barcode cannot be decoded, no graphic representation of the barcode is shown.



Close examination of this barcode reveals the problem.

The symbol does not have the correct number of bars and spaces on the right half of the barcode, hence it will not have the correct number of transitions through the Global Threshold to make it a valid UPC symbol.

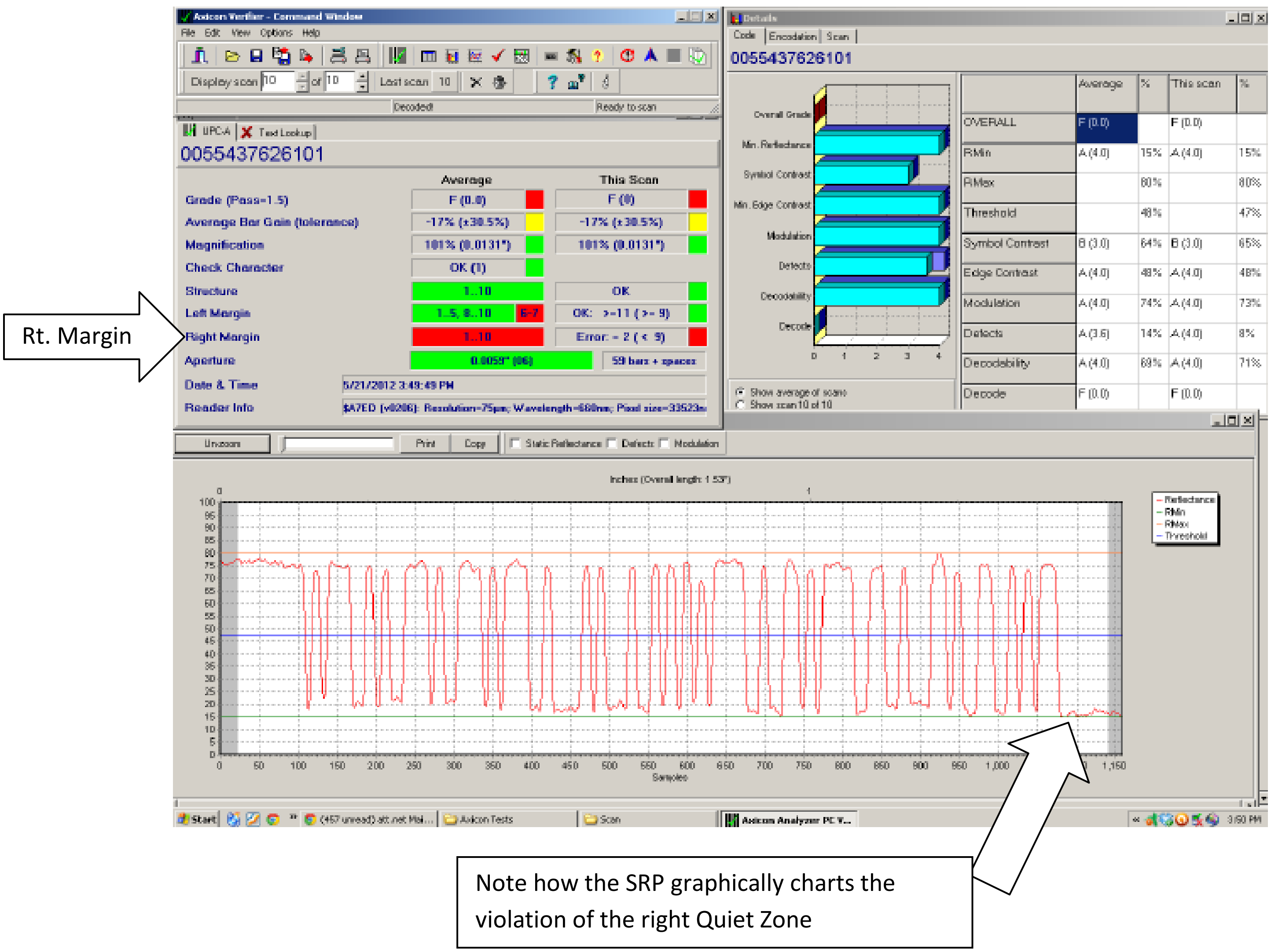
Here is a verification report showing a Decode failure on a different symbol. Notice the transition failures at the Global Threshold.



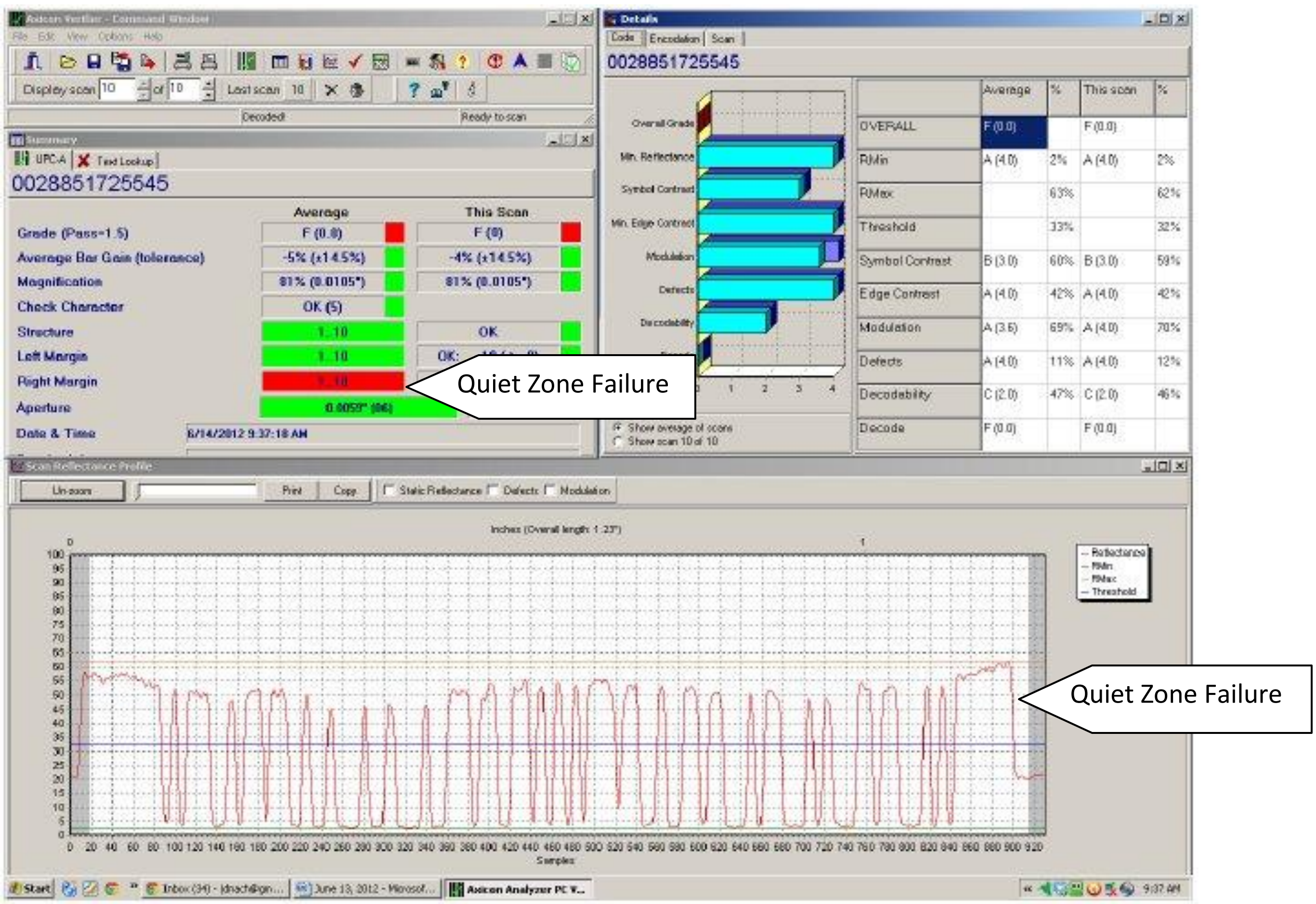
Quiet Zones

Quiet Zones are the blank areas at the beginning and at the end of the barcode. All linear barcodes require quiet zones, and the minimum width is specific to the symbology type.

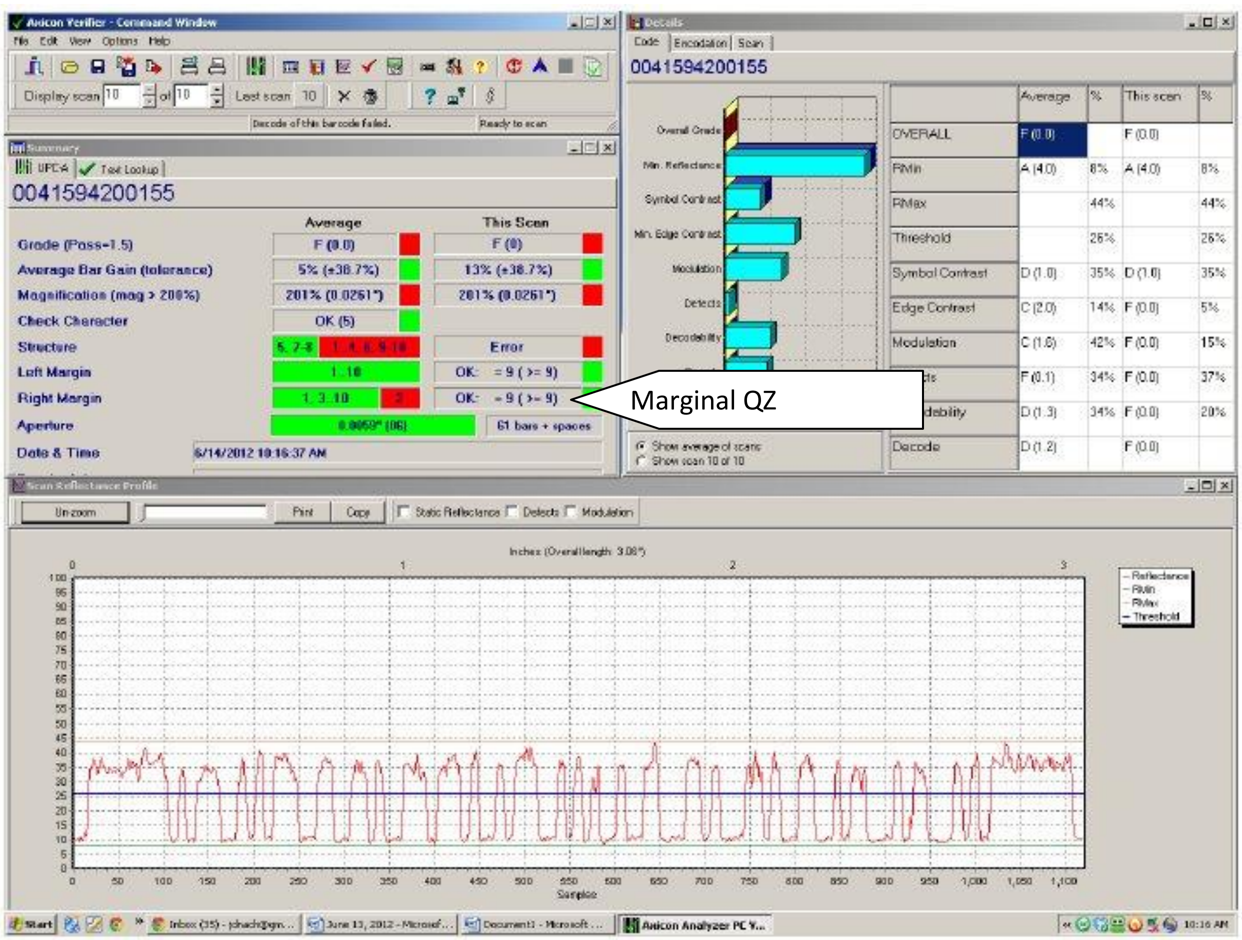
Because scanners decode the symbol by detecting predictable (within a tolerance) reflectance differences across the barcode, it is important when designing and printing a barcode to position it in a defined area, devoid of extraneous reflective differences such as screening, graphics, text, package corners, shrink wrap seams or folds or anything else that the scanner might detect and add to the element count on the Scan Reflectance Profile. Decoding occurs perpendicular to bar height, so quiet zones are only necessary to the left and right of the barcode—not top and bottom.



It is also important that the quiet zones as well as the entire background behind the barcode be a uniform reflectance value. Within a Scan Reflectance Profile there is only one Rmax and Rmin value




Quiet Zone
Failure
FOOE 163859
0 28851 72554 5
424012
Die No. 118
8/2011
BOSCH


Marginal QZ
Axicon Verifier - Command Window
Details
0041594200155
Grade (Pass=1.5)
Average Bar Gain (tolerance)
Magnification (mag > 200%)
Check Character
Structure
Left Margin
Right Margin
Aperture
Date & Time
Average
This Scan
OVERALL
RMin
RMax
Threshold
Symbol Contrast
Edge Contrast
Modulation
Decode
Scan Reflectance Profile

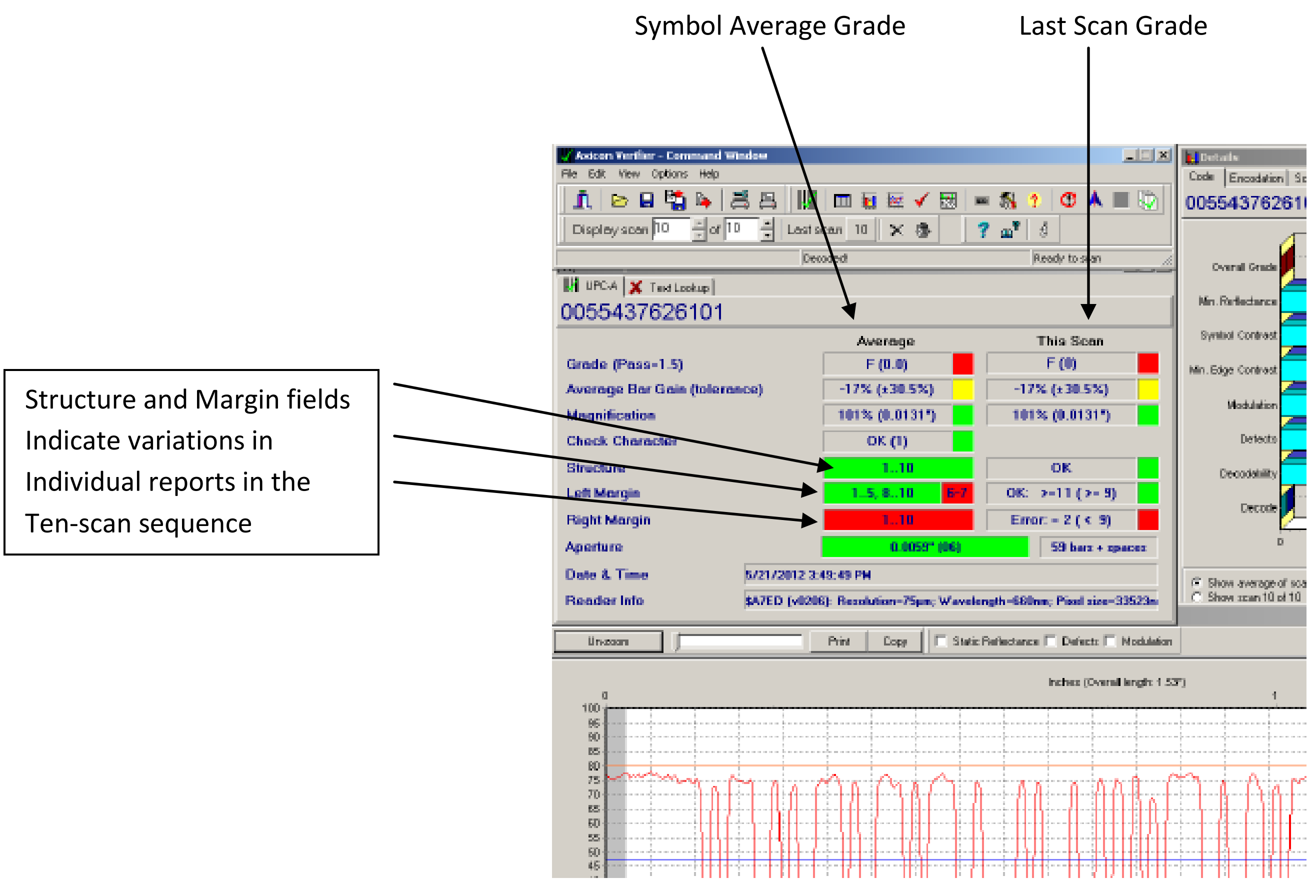

0 41594 20015 5
Marginal QZ will fail when barcode is spread or pressure fattens bearer bar

Scan Grade and Symbol Grade

Scan Grade is the grade for each individual scan of a symbol. It is not unusual for there to be slight variations in scan grades in different locations of the symbol's height.

In the ANSI/ISO grading system the scan grade is the lowest grade for any parameter. The scan grade is an average of the parameter grades or otherwise calculated in any way: the lowest parameter grade is the scan grade. This is because a failure in any one parameter can cause the decoding of the barcode to fail.

Symbol Grade is the average of multiple scan grades. The ANSI/ISO grading system recommends that the Symbol Grade be the average of ten scan grades, but fewer than ten scan grades can be averaged if the barcode does not have sufficient vertical redundancy or height for the operator to easily take ten scan grades in discreet locations.



Hypothesizing Scanability from Symbol Grade

An ANSI “A” or ISO 4.0 Symbol Grade does not “guarantee” that a barcode will successfully scan everywhere. Nor does an ANSI “F” or ISO 1.0 Symbol Grade “guarantee” that a barcode will fail everywhere.

Symbol Grade is a guideline, a predictor but not a certification of scanning success. This is because scanning technology is an ever-changing, ever-broadening mix of varying optics, varying electronics and varying firmware. In-use scanners are aging and subject to varying degrees of rough handling, in different and varying environments; new scanners are redefining and optimizing these opto-electronic technologies.

The unit of measure for the verifier grade protocol is one scan. This is also known as “first read rate”. A barcode with Symbol Grade A will generally scan successfully on the first try.

- Symbols with a C or better grade have a high probability of scanning on every well maintained scanner that is suitable for the symbology and the X dimension.
- Symbols with A and B grades rarely scan measurably better than C grade symbols, however their higher quality allows for some degree of degradation in the field caused by fading, surface wear, dust, or protection by a transparent covering.
- Typically a larger C graded symbol will perform better than a smaller A graded symbol.
- Symbols with a D or F grade will scan successfully on some scanners but at all on others

A symbol with a Symbol Grade D may require multiple scans in different parts of the barcode to decode successfully. When Symbol Grade D results can be anticipated, such as barcodes printed on corrugated, users should specify scanners that perform best in that application. F grade symbols are unlikely to scan successful in some or many scanning environments. Users sometimes believe that F grade symbols are actually acceptable because the verifier was able to decode them. The most important thing is the Symbol Grade, not the successful decode. Verifiers and scanners differ in this regard.

It is always best to attempt to print symbols of highest quality. This provides a margin of safety for what may happen downstream that might degrade the symbol quality.

How the Symbol Grade is obtained is an important consideration. The verification process should never be “optimized”. The test samples should be representative of the entire print run, usually drawn from the beginning and the end of the run, with in-process samples pulled periodically during the run.

The tested samples should always be in their final form exactly as they are ultimately presented to the end-user scanner. If they are shrink wrapped in final form, they should be shrink wrapped when they are verified. If they are inserted into a plastic case, they should be in the plastic case when verified. If they are on translucent plastic bottles with a colored liquid inside, they should be verified accordingly.

The process is every bit as important as the verification device itself. The verifier should be an ANSI/ISO compliant device. It is meaningless to use a quality testing tool without an established performance benchmark. For the same reason, the verifier should be calibrated in accordance with your ISO protocol or some other reasonable standard of practice.

Glossary of Terms

ANSI Verification	A barcode quality testing method based mostly on reflectivity where grading is expressed alphabetically (A, B, C, D, F)
Check Digit	A pass/fail traditional parameter based on the presence (where applicable) of a correctly calculated security digit
Decodability	A graded ANSI/ISO parameter based on the amount of tolerance remaining for the scanner after the imaging process.
Decode	A pass/fail ANSI/ISO parameter based on whether or not the correct pattern of bars and spaces are detected and known to be consistent with a valid barcode symbology
Defects	A graded ANSI/ISO parameter based on the presence and size of artifacts in the spaces or voids in the bars of a barcode
Edge Contrast	The reflectance difference between adjacent bar and space; the minimum edge contrast is the smallest edge contrast within a scan reflectance profile.
Edge Determination	A pass/fail ANSI/ISO parameter based in whether the number of bars and spaces match a known, valid type of barcode symbol.
Global Threshold	A horizontal or "equatorial" line exactly half way between the highest reflectance and lowest reflectance value on the SRP
ISO Verification	A barcode quality testing method based mostly on reflectivity where grading is expressed numerically (4.0 - 0.0)
Minimum Reflectance (R_{min})	A pass/fail ANSI/ISO parameter based on whether the minimum reflectance value of at least one bar is less than or equal to one half of the highest reflectance value of at least one space.

Modulation	A graded ANSI/ISO parameter based on the ratio of the minimum edge contrast to symbol contrast.
Press Gain	The physical spreading of a printed feature such as a bar due to ink wicking and/or impression force or pressure
Quiet Zone	A pass/fail traditional parameter based on the presence of a minimum blank space preceding and trailing a barcode
Reflectance	A measure of the amount of light reflected from an illuminated surface
Scan Grade	The grade for each individual verification scan of a symbol
Scan Reflectance Profile (SRP) **Symbol Grade**	A graphical representation of the light and dark reflectance values of a barcode symbol The ten-scan average (or some other total number) grade of a symbol
Symbol Contrast	A graded ANSI/ISO parameter based on a straight subtraction of the minimum reflectance value from the maximum reflectance value
Traditional Verification	A barcode quality testing method based mostly on element (bar and space) width measurement and comparison to nominal or idea values.