Layman's Guide
to
ANSI X3.182

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1 Introduction

The first published document concerning the issue of printed bar code quality was the Uniform Code Council (UCC) Universal Product Code (U.P.C.) Symbol Specification and U.P.C. Verification manuals. Quality parameters for checking the quality of bar codes had to do with:

- Did the bar code meet the required format structure?
- Did it have the right characters in the right positions?
- Did it have the correct number of encoded characters?
- Did the background and bar contrast (color) or reflectance meet the correct criteria for a bar code scanner to “see” the bar code? (At that time, scanners where primarily based on helium neon lasers which “see” everything as if it had red glasses on.)
- Did the widths of the bars and spaces meet the industry specifications?
- Were the quiet zones wide enough?
- Was the height of the bar code correct?

In 1982 the American National Standard Institute, (ANSI) X3A1 Technical Sub-committee with the assistance of other ANSI and industry committees and bar code authorities, began studying the issue of bar code print quality. Through the years, bar codes had been printed that met the existing standards, but would not scan. More often bar codes printed out of specified standards did scan.

This combined group knew that the existing specifications for quality control of bar codes were evaluating criteria based on the way the human eye “viewed” the bar codes. This was not the way any bar code scanner would “see” the bar code. A bar code scanner is an optical device and does not incorporate human eye optical properties when “looking” at a bar code. The ANSI X3A1 group evaluated what factors were important to the many different types of bar code scanners/decoders for high first read rates and readability. After eight years of extensive testing, American National Standard X3.182-1990 Bar Code Print Quality Guideline was published. That document outlines quality parameters based on the optics of bar code scanning systems.

Today many groups including the UCC, ANSI/Material Handling Institute and Automotive Industry Action Group have specified conformance to ANSI X3.182 1990 Bar Code Print Quality Guideline. The present literature will outline the parameters of bar code quality from the ANSI document. It will discuss the importance of these parameters, and what corrective action is necessary to greatly improve bar code print quality.

2 Aperture and Wavelength

The aperture size and wavelength has a significant impact as to the grade results obtained. For instance, a symbol checked with a 5 mil aperture with a 633 nm (red) wavelength light source might achieve a grade of D (poor). The same symbol could be verified with a 10 mil aperture at the same wavelength and receive a grade of B (good), and then receive a grade F (fail) if verified with a 10 mil aperture with a 900 nm (non-visible light source. The ANSI guideline also recommends the aperture diameter based on the “X” dimension of the bar code being verified. The aperture and wavelength specified in ***Industry Application Standards*** takes precedence over the ANSI guideline, even if some X dimensions ranges do not agree with the ANSI recommendations.

DIAMETER (in .001")	“X” DIMENSION RANGE
03	.004" to 007"
05	.0071" to .013
10	.0131" to .025"
20	.0251" and larger

3 Scan Reflectance Profile

The ANSI X3.182-1990 Bar Code Print Quality Guideline outlines several parameters that greatly effect the quality of the printed bar code.

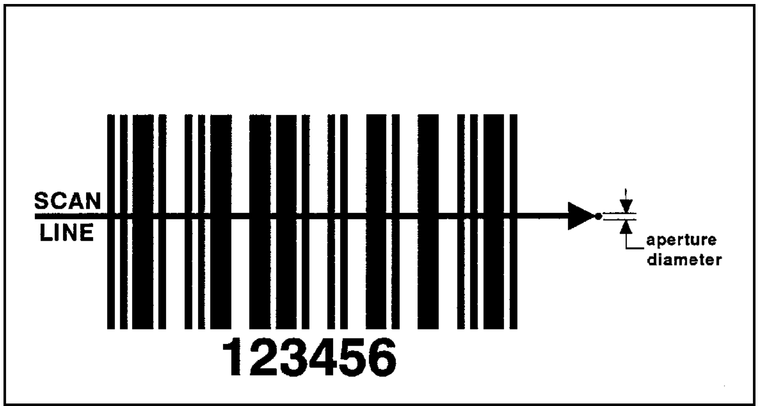

Figure 1: Scan Line through a Bar Code

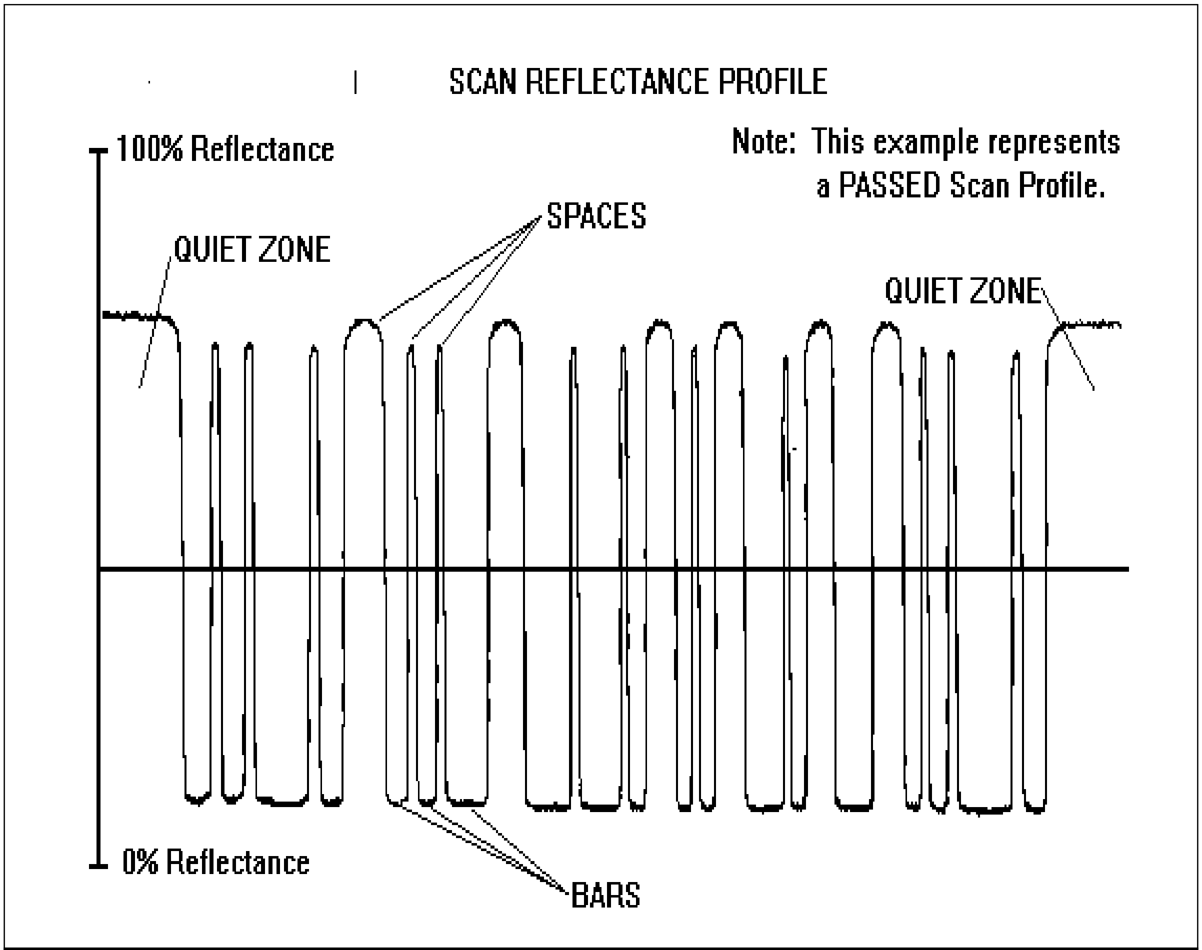

Figure 2: Passing Scan Reflectance Profile

These parameters are tested by creating a Scan Reflectance Profile. A Scan Reflectance Profile is a record of the reflectance values (00% to 100%) measured along a single line across the entire width of the bar code. Figure 1 illustrates a scan line passing through a bar code symbol that would be used to generate the scan reflectance profiles that are illustrated in this document. These values are charted to create an analog representation of the bar code. Each Scan Reflectance Profile will either Pass, Fail or be graded as A, B, C, D, OR F *(referred to as a Scan Grade)* for one or possibly more of specified criteria as described in the ANSI document and further explained in this document. Ten Scan Reflectance Profiles are required to determine *Symbol Grade.* (See figure 2 for a Passing profile and figure 2A for a Failing profile.

After creating the Scan Reflectance Profile, a count of the elements (bars and spaces) is done to determine if the bar code conforms to some type of symbology. But before this can be accomplished, Edge Determination must be done.

3.1 Edge Determination (Pass/Fail)

GT = Global Threshold
R_{min} = Reflectance Minimum
SC = Symbol Contrast

Formula:

$$GT = R_{min} + SC/2$$

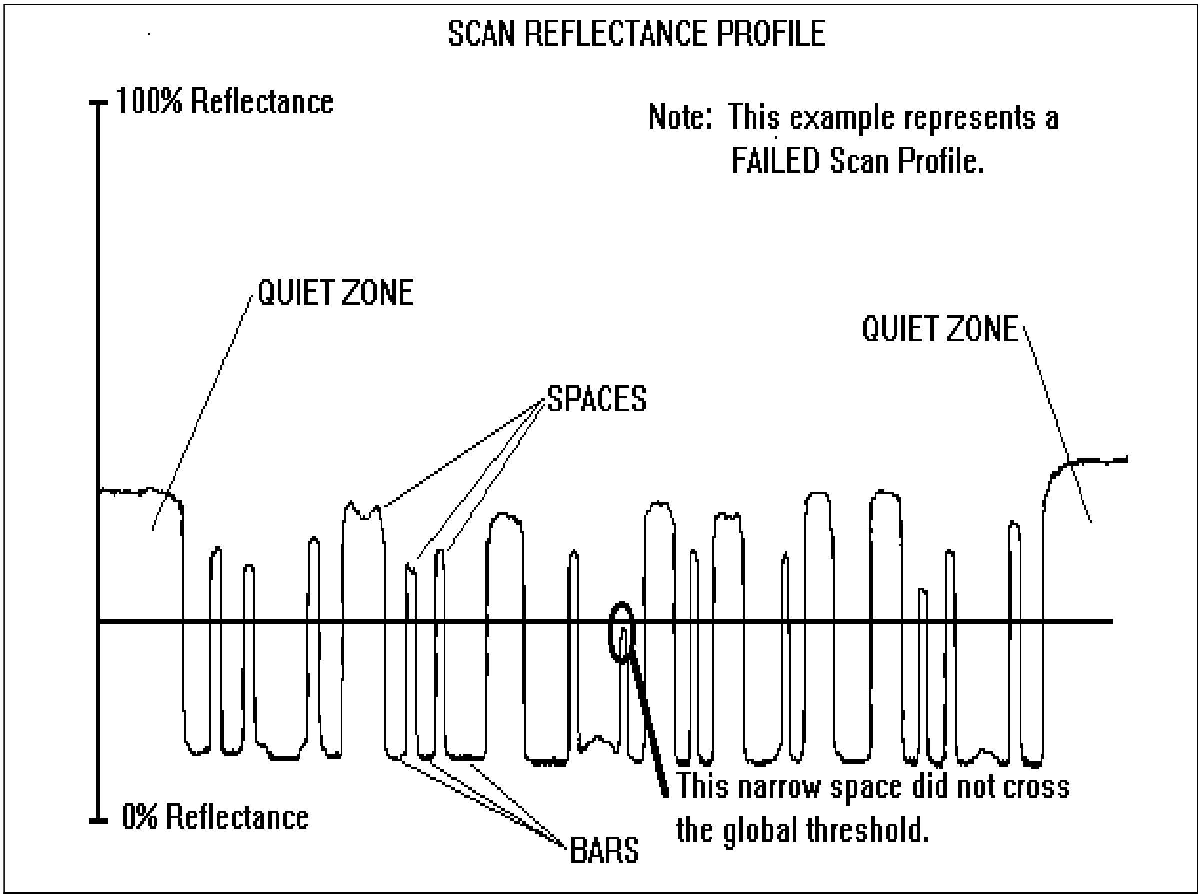

Figure 2A: Failed Scan Reflectance Profile

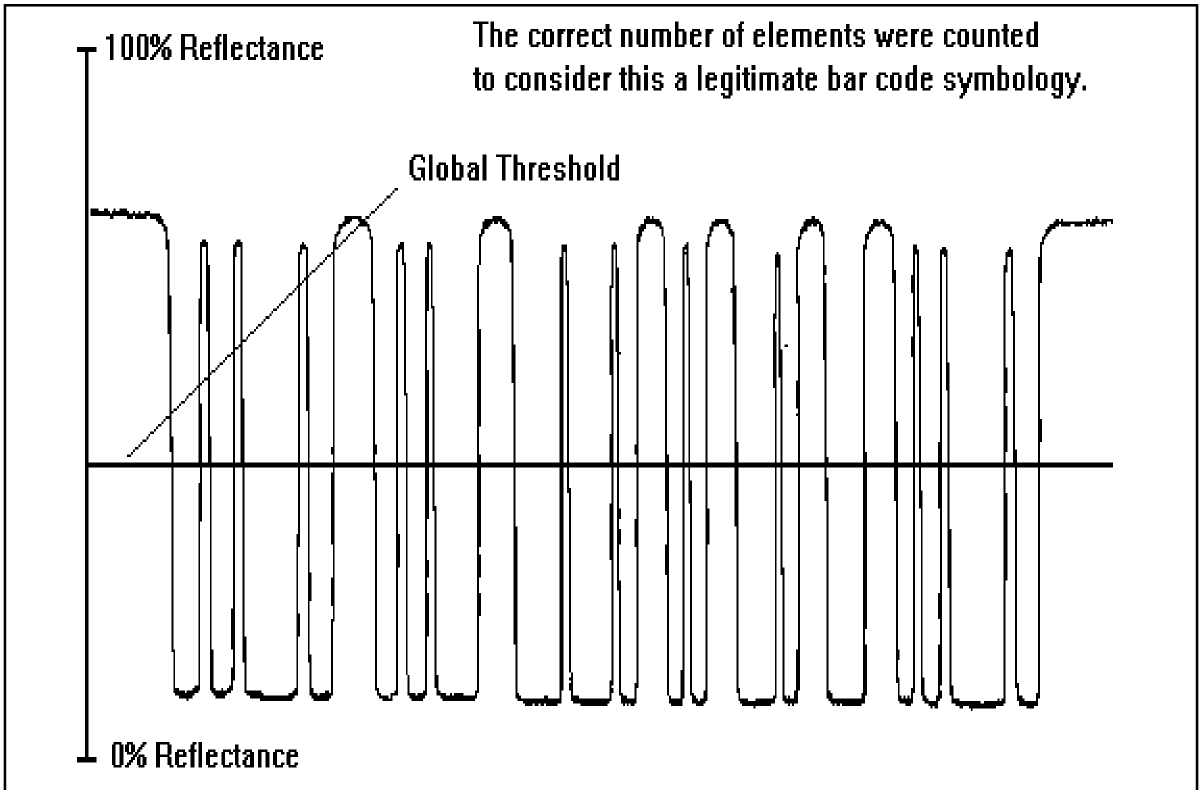

Figure 3: Passed Edge Determination

Definition:
In order to discern bars and spaces, a Global Threshold is established on the scan reflectance profile by drawing a horizontal line half way between the highest reflectance value and the lowest reflectance value seen in the profile. Edge Determination can then be done by counting the number of crossings at the Global Threshold confirming whether the count conforms to or is considered non-conforming to a legitimate bar code symbology. If the bar code conforms it Passes; if it is considered non-conforming it Fails. (See Figure 3 for a Pass on Edge Determination and Figure 3A for a Fail on Edge Determination)

After the bar code has passed Edge Determination, there are seven parameters that must be tested. Of these parameters 3 are either Pass or Fail and 4 are graded A, B, C, D or F, where A is the best and F equals a Fail.

The testing of these parameters are done in sequence as is shown in the flow chart in figure 9.

3.2 Minimum Reflectance (Pass/Fail)

R_{min} = REFLECTANCE MINIMUM
R_{max} = REFLECTANCE MAXIMUM
Formula:
R_{min} £ .5 R_{max} = Pass
$R_{min} > .5 R_{max}$ = Fail

Definition:
The reflectance value for at least one bar must be half or less than the highest reflectance value for a space. If the highest space reflectance value is equal to 80% the reflectance value of at least one bar in the profile must be 40% or less. (See figure 4 for a Passing Minimum Reflectance and figure 4A for a Failing Minimum Reflectance)

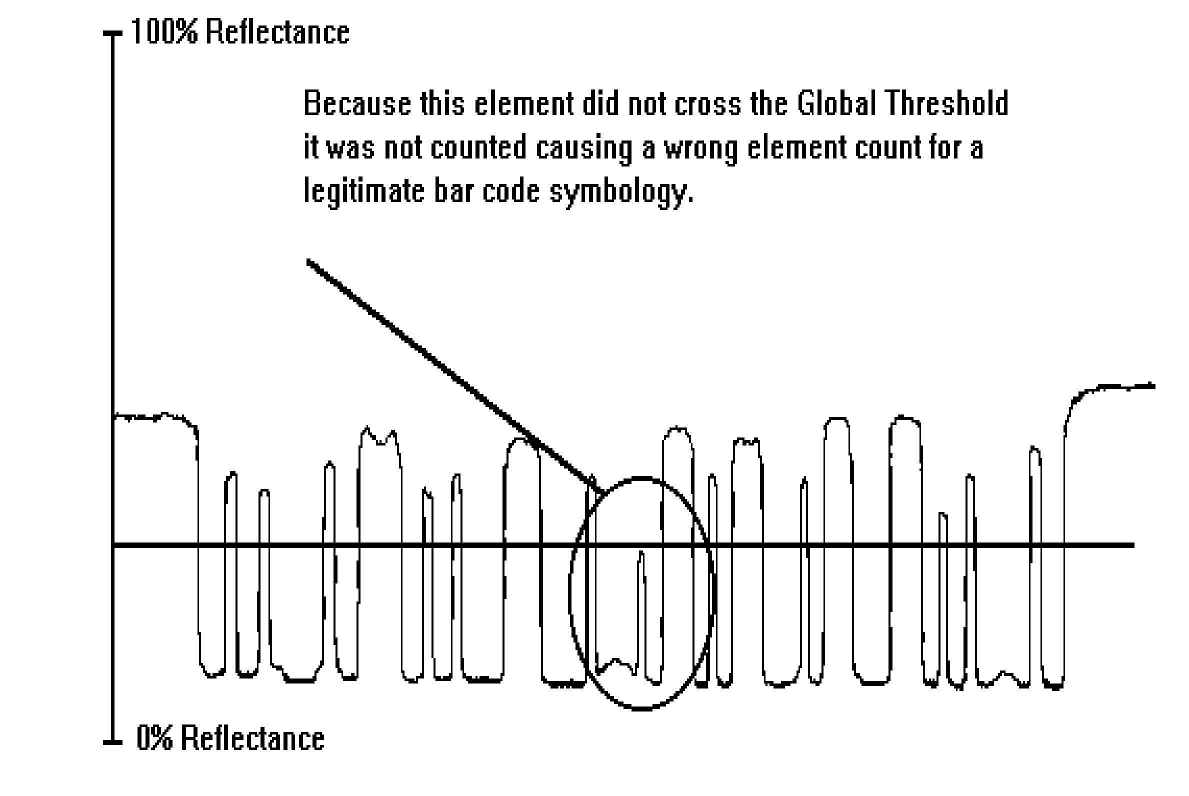

Figure 3A: Failed Edge Determination

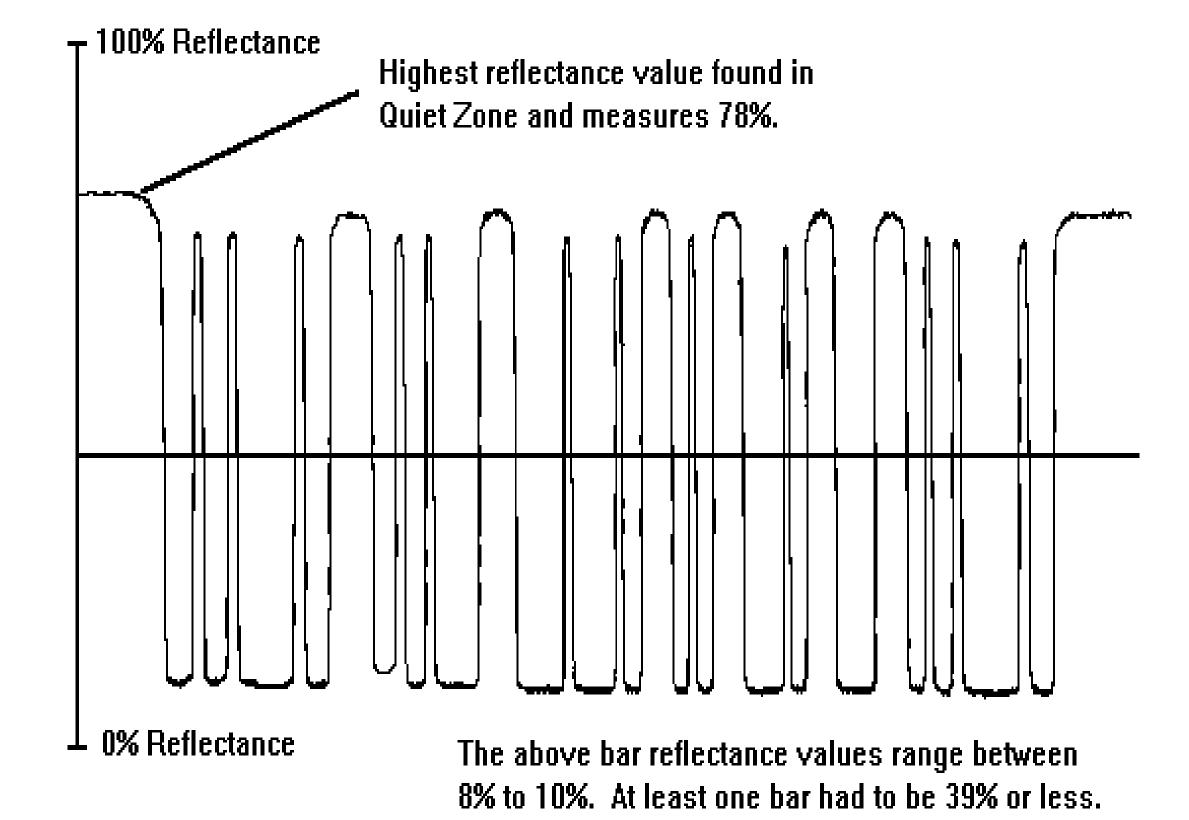

Figure 4: Passing Minimum Reflectance Test

Suggestions for improving Minimum Reflectance:

Making bars darker, i.e. darker ink or for thermal printing increasing heat.

3.3 Minimum Edge Contrast ,EC_{min} (Pass/Fail)

Rs = Space Reflectance
Rb = Bar Reflectance

Formula:

$EC_{min} = Rs_{min} - Rb_{max}$ (worst pair)

$\geq$ 15% = Pass
< 15% = Fail

Definition:
Each transition from a bar to a space, or back again, is an "edge" whose contrast is determined as the difference between peak values in that space and that bar. Each edge in the scan profile is measured, and the edge that has the minimum contrast from the transition from space reflectance to bar reflectance, or from bar to space, is the Minimum Edge Contrast or EC_{min}. (See figure 5 for a Pass on EC_{min} and figure 5A for a Fail on EC_{min})

Suggestions for improving Minimum Edge Contrast (EC_{min}):

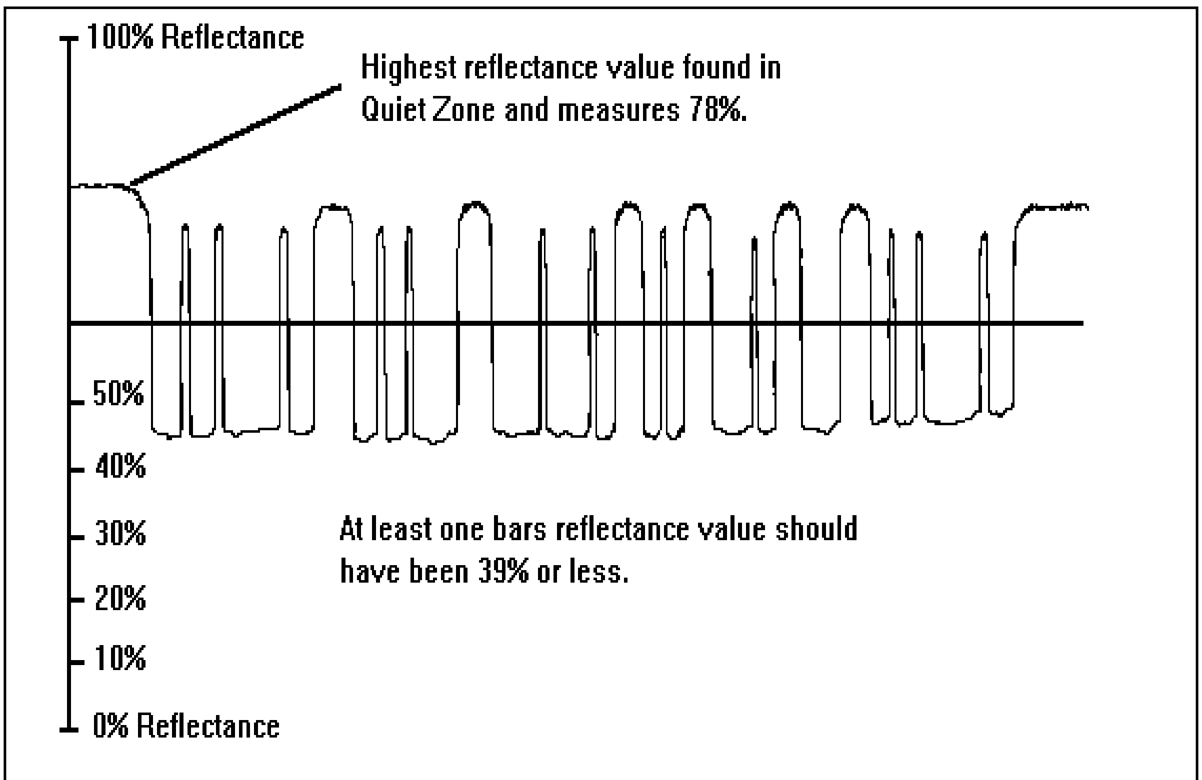

Figure 4A: Failing Minimum Reflectance Test

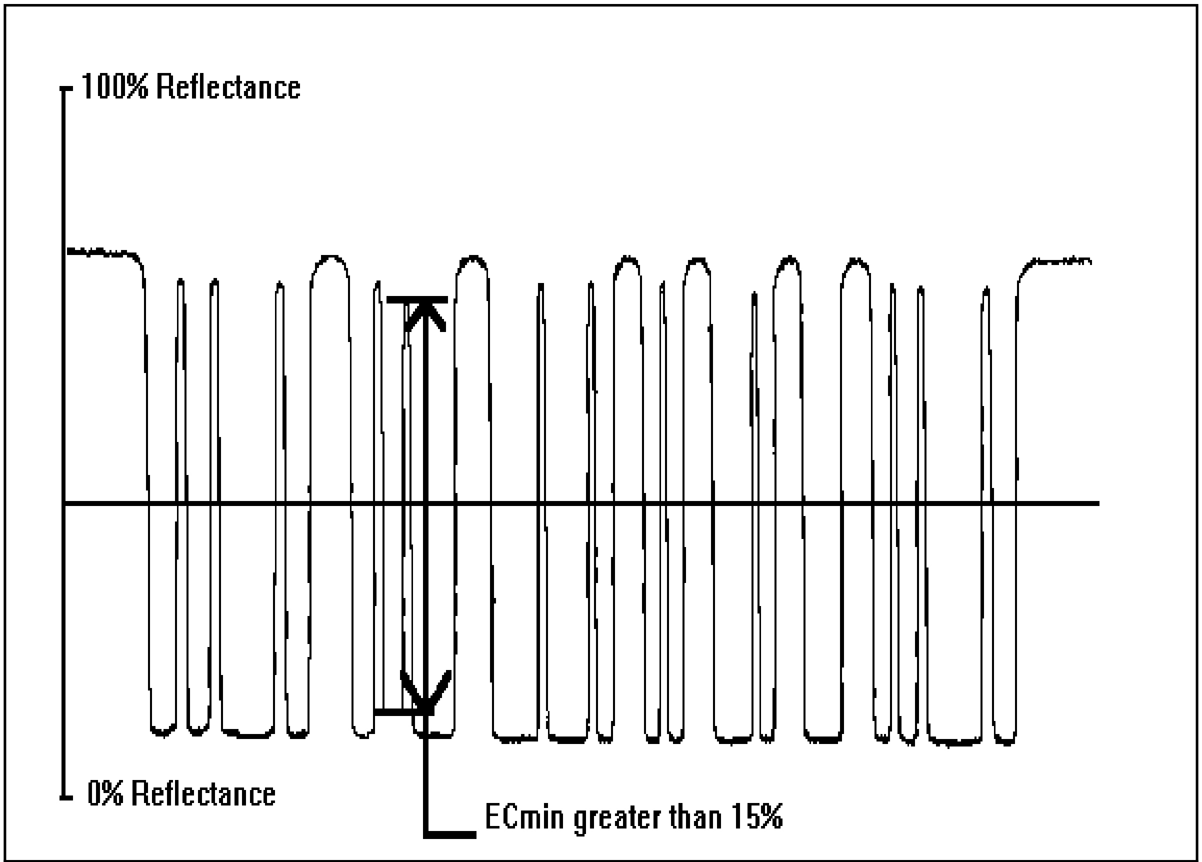

Figure 5: Passing Minimum Edge Contrast

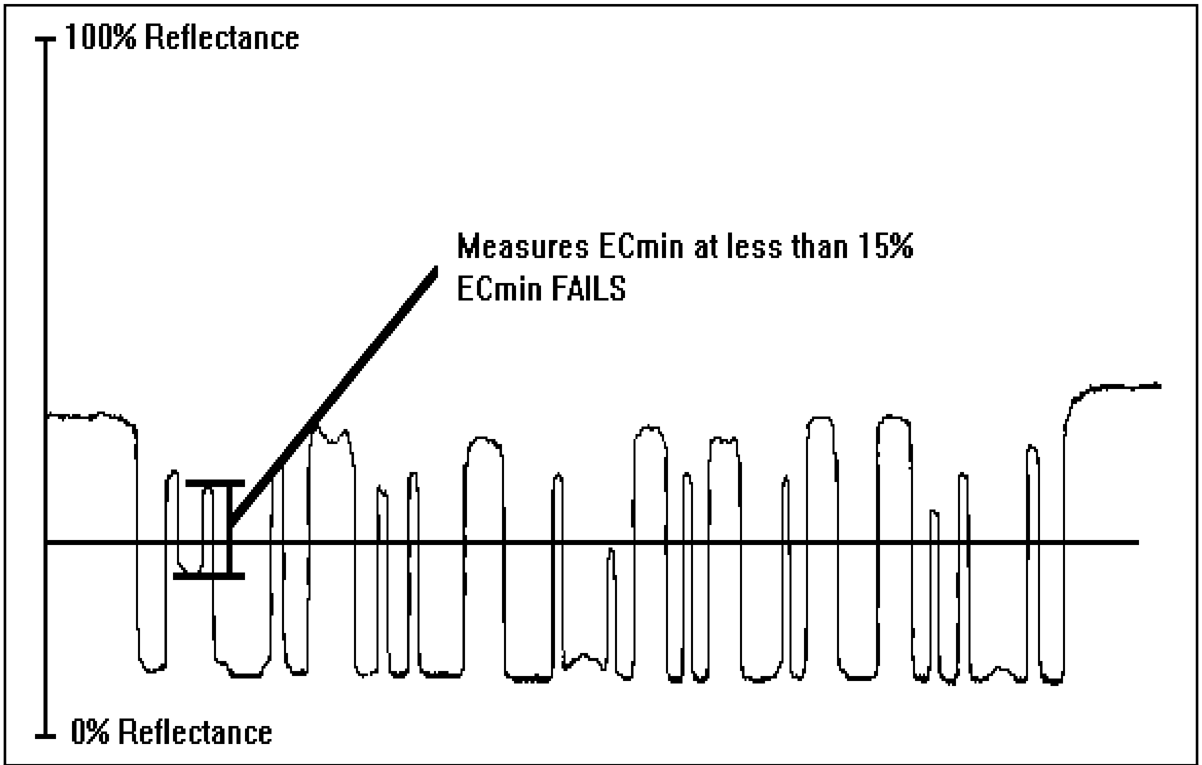

Figure 5A: Failing Minimum Edge Contrast

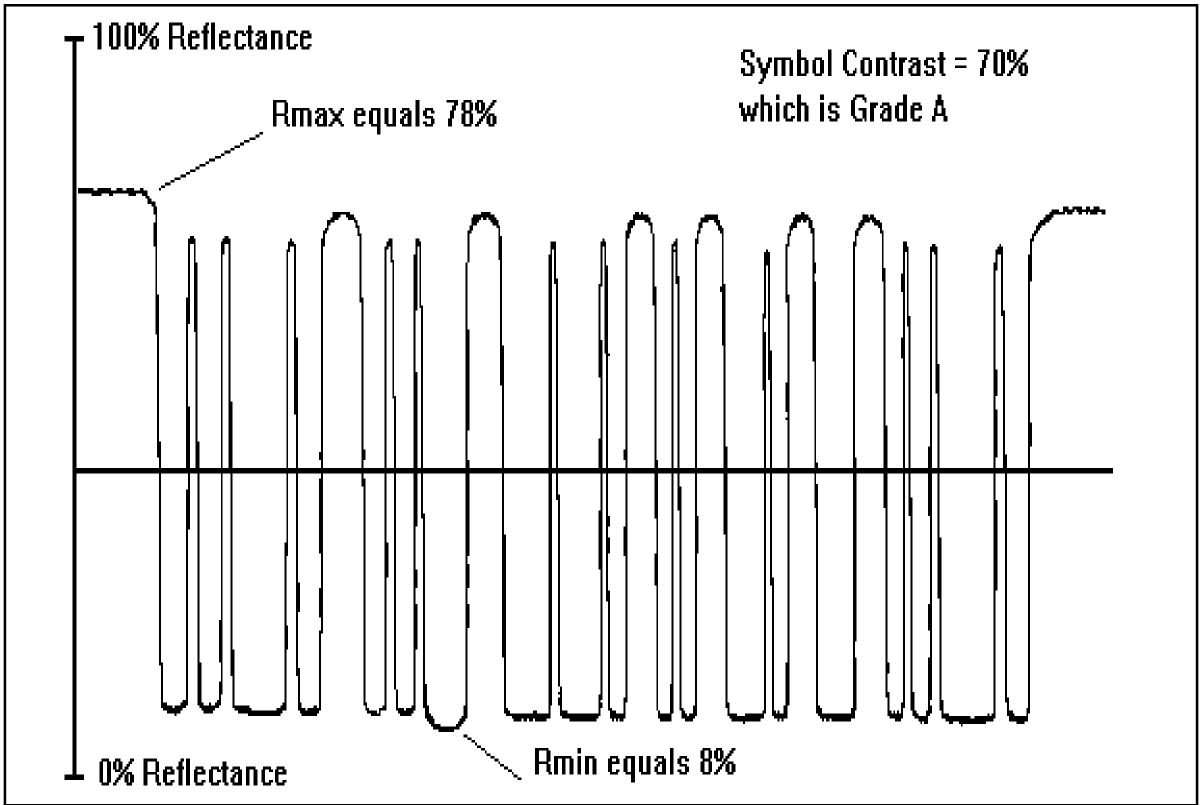

Figure 6: Grade A Symbol Contrast

Using a “lighter” substrate and darker ink, or increasing the X dimension (minimum element width), assuming the appropriate aperture size is used.

3.4 Symbol Contrast, SC (Graded)

SC = Symbol Contrast
R_{max} = Reflectance Maximum
R_{min} = Reflectance Minimum

Formula:

$SC = R_{max} - R_{min}$

$\geq$ 70% = A
$\geq$ 55% = B
$\geq$ 40% = C
$\geq$ 20% = D
< 20% = F

Definition:
Symbol Contrast is the difference between the highest reflectance value and the lowest reflectance value in the scan profile. The higher the value the better the grade. (See figure 6 for a grade A Symbol Contrast and figure 6A for a grade F Symbol Contrast)

Suggestions on improving Symbol Contrast:

Make the bars darker and the spaces lighter or less shiny. Shiny materials such as laminates, polished metals and high gloss are a special case as they usually fail to reflect much light back in the direction it was received. This causes the reflectance values to be lower in those shiny areas.

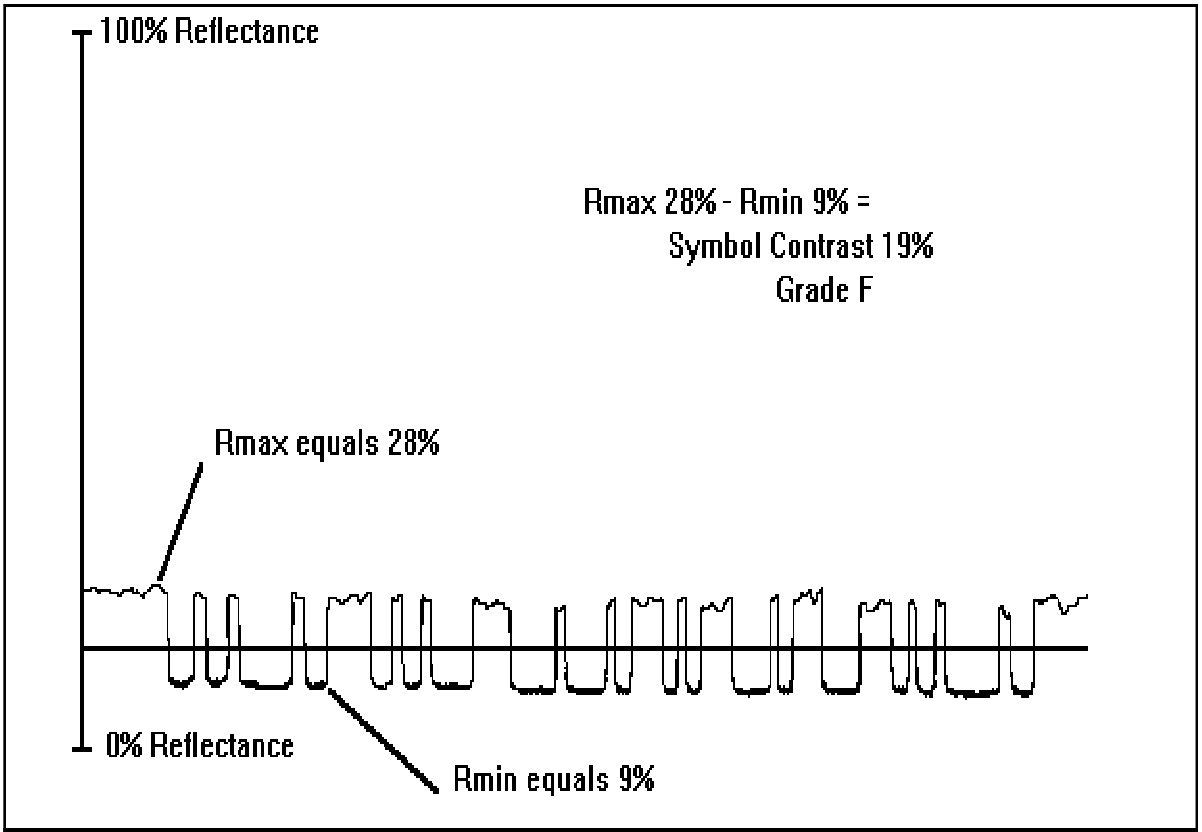

Figure 6A: Grade F Symbol Contrast

3.5 Modulation (Graded)

EC_{min} = Edge Contrast Minimum
SC = Symbol Contrast

Formula:

EC_{min}/SC

³ .70 = A
³ .60 = B
³ .50 = C
³ .40 = D
< .40 = F

Definition:
Modulation has to do with how a scanner "sees" wide elements (bars or spaces) in relationship to narrow elements, as represented by reflectance values in the scan profile. Scanners usually "see" spaces narrower than bars and scanners typically "see" narrow spaces being even less intense or not as reflective as wide spaces. (See figure 7 for grade A on modulation and figure 7A for a grade F on modulation.)

Suggestions for improving Modulation grade:

Making narrow spaces wider than the narrow bars usually will increase the Modulation grade. Measuring with a smaller aperture will often increase the Modulation grade, but the measurement aperture should always be the correct one for the application.

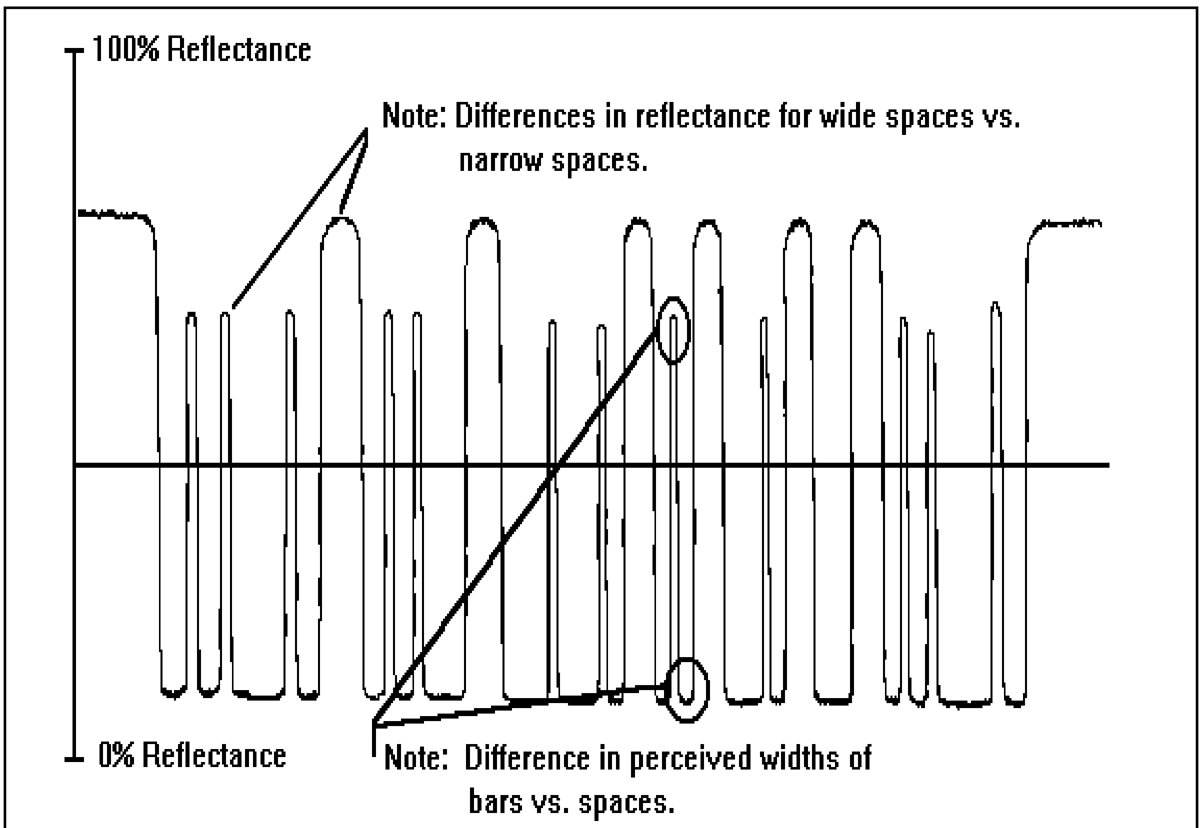

Figure 7: Grade A Modulation

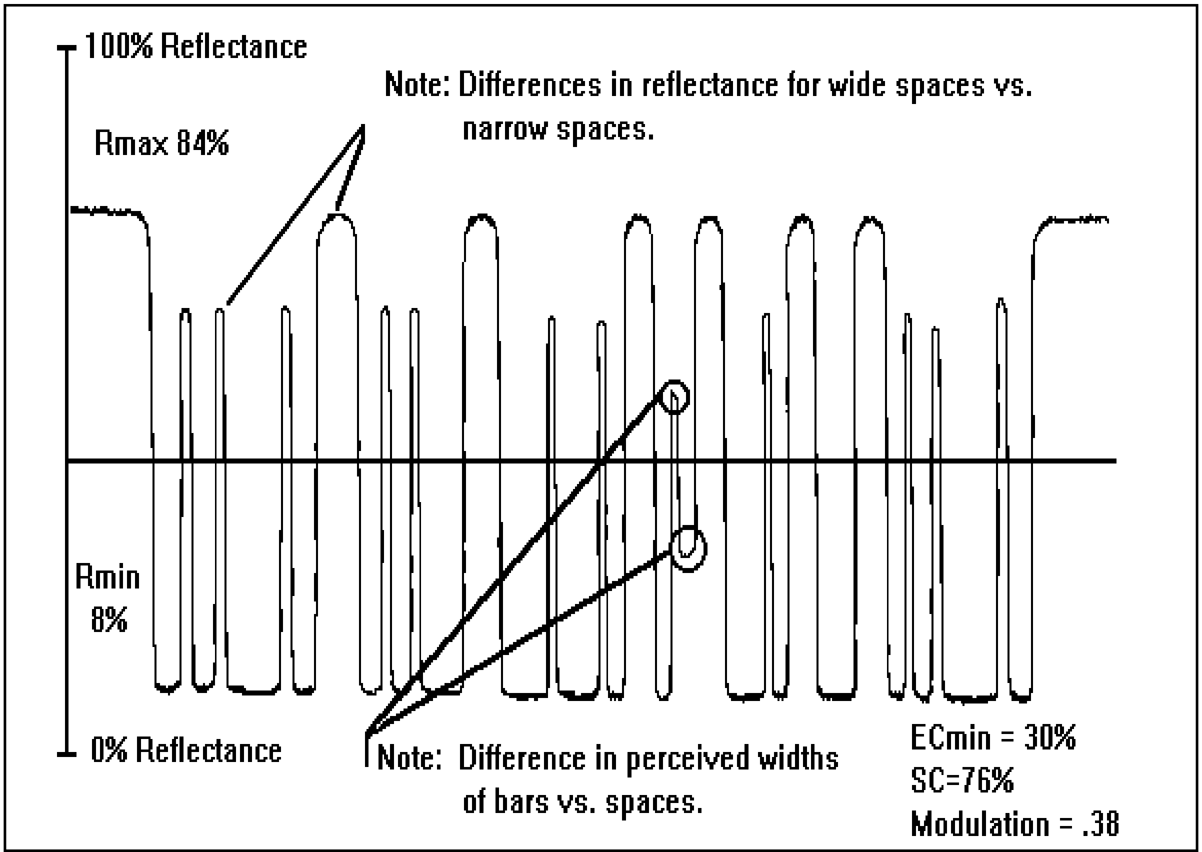

Figure 7A: Grade F Modulation

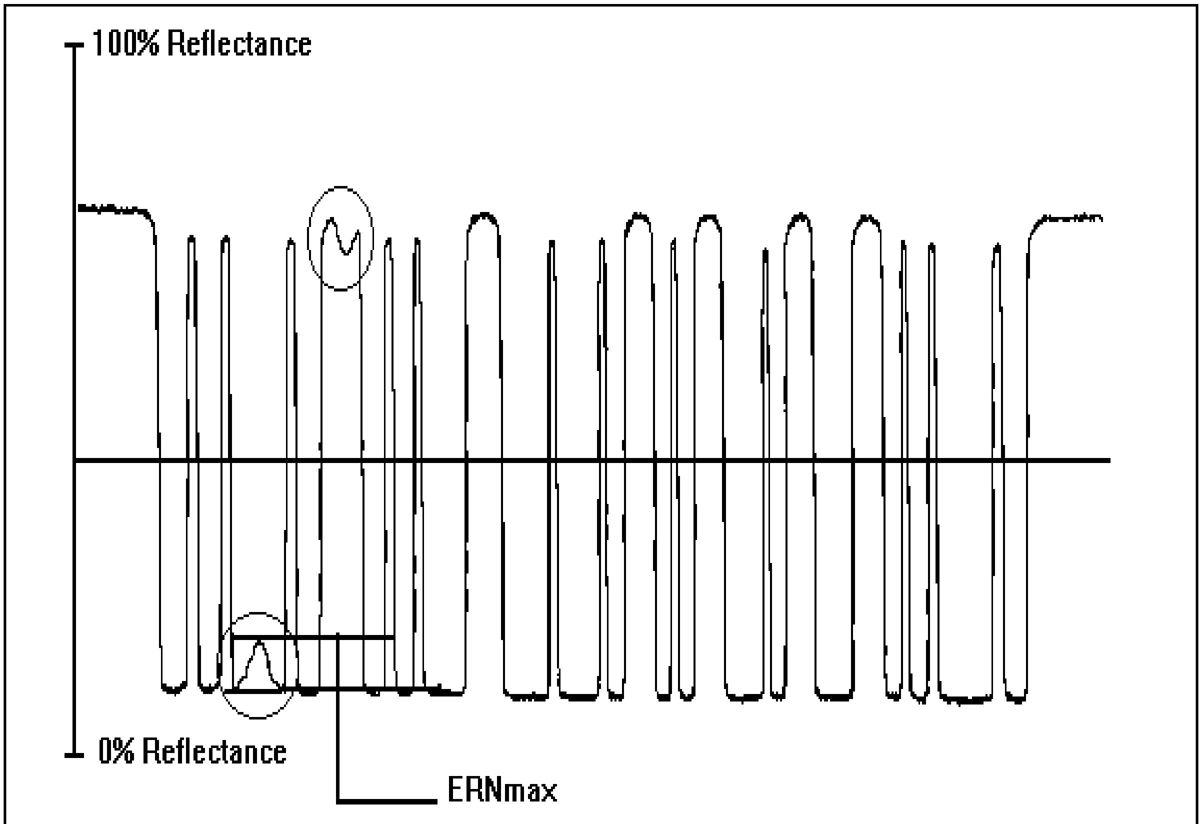

Figure 8: Grade A Defects

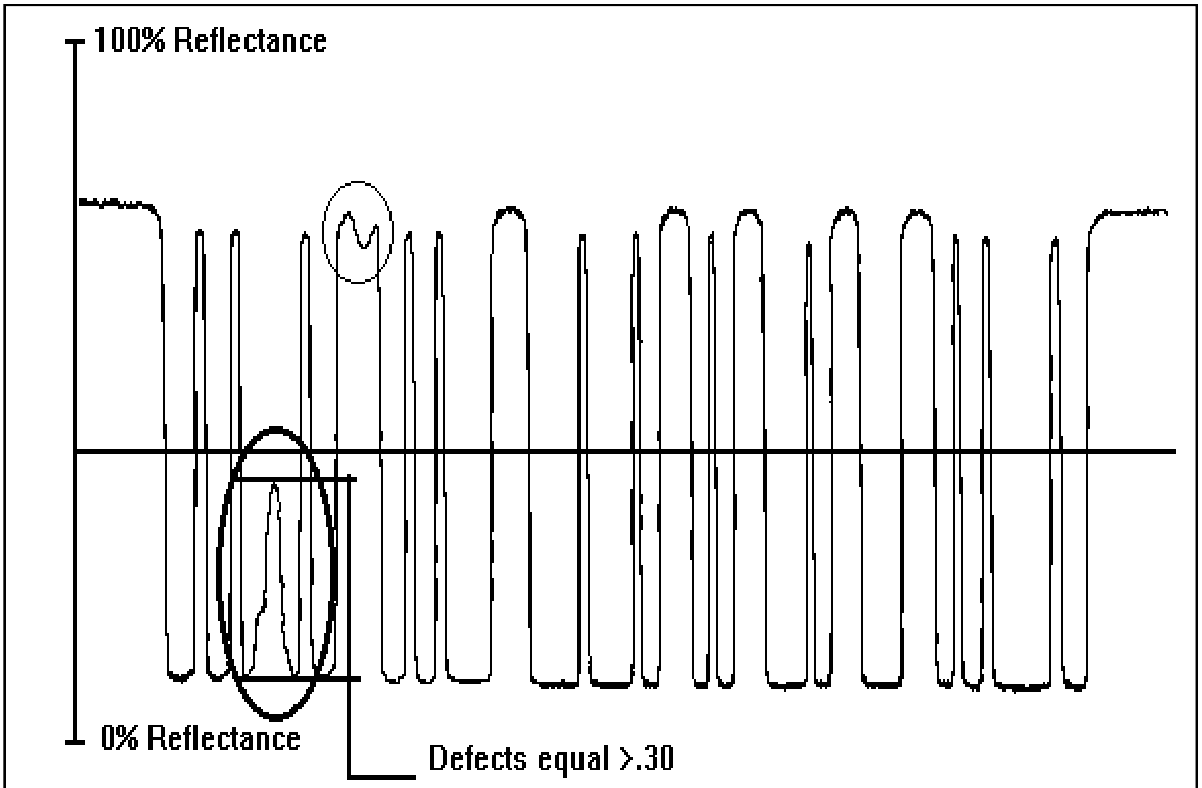

Figure 8A: Grade F Defects

3.6 Defects (Graded)

ERN_{max} = Element Reflectance Non-uniformity
SC = Symbol Contrast

Formula:

ERN_{max}/SC

£.15 = A
£.20 = B
£.25 = C
£.30 = D
>.30 = F

Definition:
Defects are voids found in bars or spots found in the spaces and quiet zones of the code. Each element is individually evaluated for its reflectance non-uniformity. Element reflectance non-
uniformity is the difference between the highest reflectance value and the lowest reflectance value found within a given element. Many elements may have zero non-uniformity. (See figure 8 for grade A in Defects and figure 8A for grade F in Defects)

3.7 Decodability (Graded)

Formula:
Different decodability calculation methods are used for each type of symbology being tested. Please refer to the ANSI X3.182-1990 Bar Code Print Quality Guideline for the formulas.

Definition:
Decodability is the measure of the accuracy of the printed bar code against the appropriate reference decode algorithm. Each symbology has published dimensions for element widths and provide margins or tolerances for errors in the printing and reading process. Decodability measures the amount of margin left for the reading process after printing the bar code.

3.8 Decode (Pass/Fail)

Definition:
A bar code will Pass on Decode when the established bar and space widths can be converted into the correct series of valid characters using the ANSI Reference Decode algorithm for a given symbology and or application.

4 Scan Grade
The Scan Grade is the lowest grade received for any quality parameter in a reflectance scan profile. For example, if a grade of A or Pass is received for all quality parameters except for Modulation, which received a grade of C, the overall Scan Grade is C.

5 Overall Symbol Grade
ANSI X3.182 states that the Overall Symbol Grade is based on ten scan profiles, and the average of their resultant scan grades as defined above. The reason for averaging ten scans is purely for vertical redundancy. Quality levels could vary within the height of the bar code being verified.

6 Numeric Conversion
It is possible to convert the Overall Symbol Grade to a Numeric grade. Since a grade A is a range of 3.5 to 4.0, this shows how close a given symbol is to achieving either a grade higher or grade lower. Please see page 15 for the flow chart and Numeric Conversions.

7 Significance of Grade Level
Bar code systems can provide good performance with differing symbol grades because of the following:
a) vertical redundancy;
b) tolerances built into decoding algorithms;
c) the ability of operators to rescan if the first read is unsuccessful;

d) the availability of scanning devices that provide for multiple, unique scan paths across the code.

The different symbol grades indicate print quality. An application specification shall identify the minimum acceptable grade level including the measuring aperture and the nominal wavelength(s).

Symbols with a grade A are the best quality and will in general give the best performance. In general, this grade symbol is appropriate for systems in which the reader crosses the symbol once or is limited to a single path.

A symbol with a grade of B may not perform to the same level as one with a grade of A. Some of these B symbols may need to be rescanned. In general, this grade is best suited for applications which require symbols to be read most of the time in a single pass of a bar code scanner but allow for rescan.

Symbols of grade C may require more rescans than those of grade B. In general, these grade C symbols may need more frequent rescanning and for best read performance a device that provides for multiple, unique scan paths across the code should be used.

A symbol of grade D is best read by bar code readers that provide for multiple, unique scan paths across the symbol. There may be symbols with a D grade that certain readers can not read. Prior to selection of a grade D symbol for a particular application, it is advised that the symbol(s) should be tested with the type of bar code reader expected to be used. The test(s) will establish that the read results are within acceptable limits and expectations.

The ANSI grading methodology, utilizing grade letter A, B, C, D, and F is intended to give an idea as to the first pass read rate based on 'real world' average reading and decoding technology. It is conceivable that bar codes obtaining scan profile grades of F may have very good first pass read rates when being read with readers/decoders that are very aggressive. The grading structure does not necessarily mean that a lower grade is bad or that the bar code will not read, but rather as compared to 'average' scanner/decoder technology, the first pass read rate will be lower.

It should be further explained that the evaluation of bar code quality must match the application. Bar codes going through multiple processes such as laminating, shrink wraps, etc. should be verified after all processes have been completed. Dependent on the application, different grades might be required for each process to obtain the final acceptable grade for the reading environment.

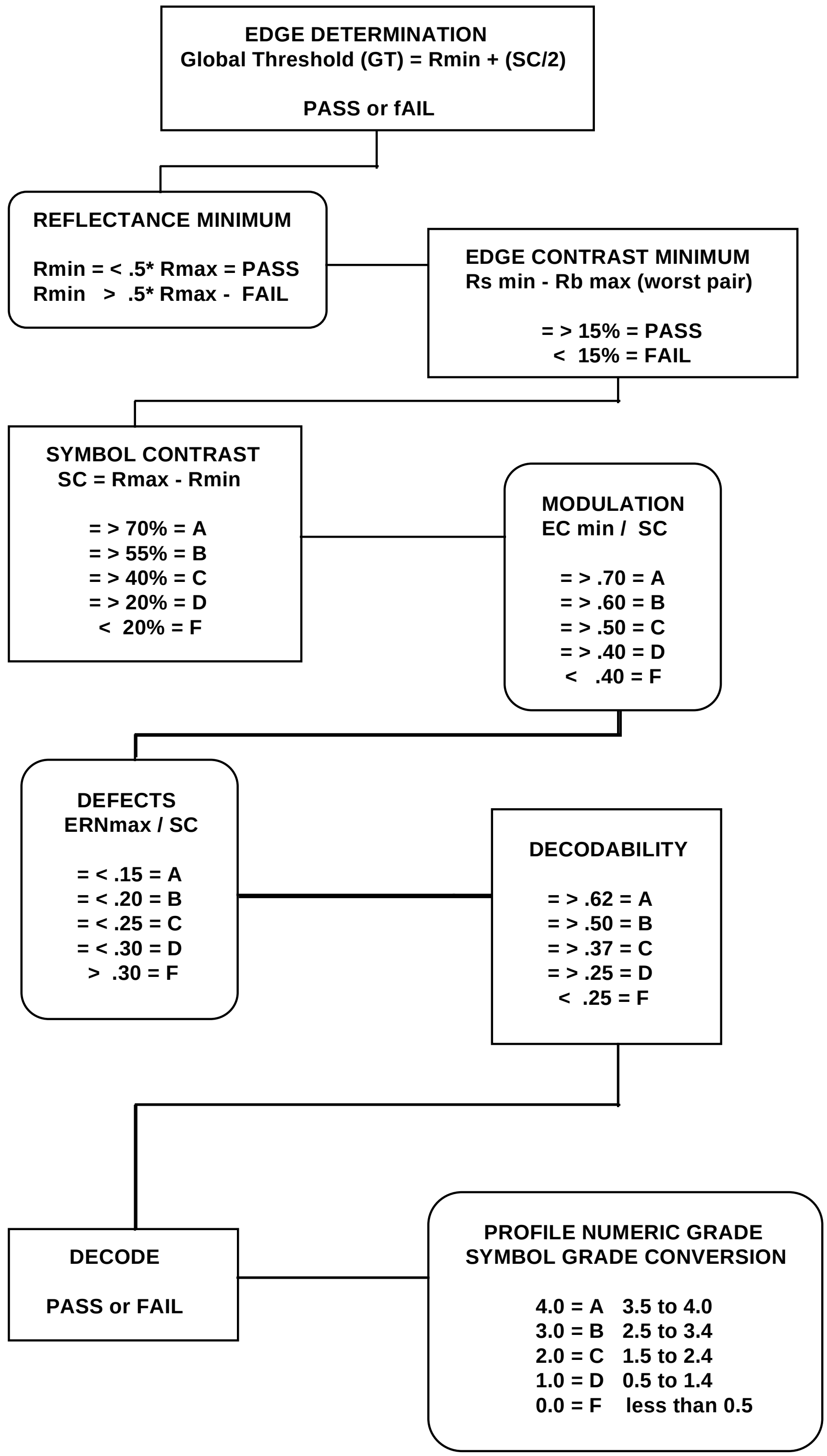

Figure 9: ANSI X3.182 Grading Flow Chart

Reference Documents

ANSI/AIM BC2 - USS Interleaved 2-of-5 (Item X5-1)
ANSI/AIM BC1 - USS Code 39 (Item X5-2)
ANSI/AIM BC3 - USS Codabar (Item X5-3)
ANSI/AIM BC4 - USS Code 128 (Item X5-4)
ANSI/AIM BC5 - USS Code 93 (Item X5-5)
ANSI/AIM BC7 - USS Code 16K (Item X5-6)
ANSI/AIM BC6 - USS Code 49 (Item X5-7)
ANSI/AIM BC12 - USS Channel Code (Item X5-12)
ANSI/AIM BC10 - ISS MaxiCode (Item X5-10)
ANSI/AIM BC11- ISS Data Matrix (Item X5-11)
ANSI/AIM BC13 - ISS Aztec Code (Item X5-13)
AIM USS - Code One (Item X5-8)
AIM USS - PDF417 (Item X5-9)
AIM ISS - QR Code (Item X5-15)
AIM ISS - MicroPDF417 (Item X5-16)
AIM ISS - Guidelines on Symbology Identifiers (Item X-50)
AIM Guidelines on MaxiCode Mode 0 (Item X5-51)
AIM Code 49 Developer's Diskette (Item Z-40)
AIM PDF417 Developer's Diskette (Item Z-46)
AIM Code One Developer's Diskette (Item Z-47)
AIM MaxiCode Developer's Diskette (Item Z-48)
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CEN Specifications
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