Code 39

Specification for Barcode Symbology

1.0 Introduction

USS-39 (nee Code 39) is a bar code symbology with a full alphanumeric character set, a unique start and stop character and seven special characters. The name 39 is derived from its code structure which is three wide elements out of a total of nine elements. The nine elements consist of five bars and four spaces. USS-39's characteristics are summarized in Table 1.

Encodable Character Set—Full Alphanumeric and,
    7 Special Characters: - . Space $ / + %
    1 Start/Stop Character: *
Code Type—Discrete
Symbol Length—Variable
Bidirectional Decoding?—Yes
Character Self Checking?—Yes
Number of Required Check Characters—None
Smallest Nominal Element—0.0075 inches (0.191 mm.)
Maximum Data Character Density—9.8 char./inch (3.7 char./cm)
Non-Data Overhead—Equivalent to 2 characters
Options—An optional check character is described in Appendix C.3

Table 1. Characteristics of USS-39

2.0 Symbol Description

Every symbol consists of:
a) Leading quiet zone
b) Start character
c) One or more data characters
d) Stop character
e) Trailing quiet zone

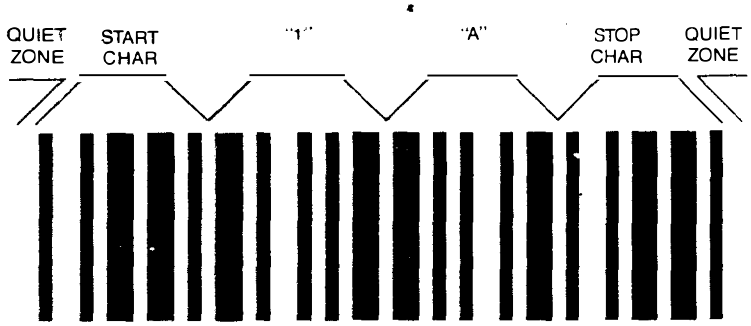

Figure 1. Encoding the message "1A"

2.1 Encodation

Each USS-39 symbol consists of a series of characters, each represented by five bars and the four intervening spaces. Each character is separated by an intercharacter gap. Figure 2 below illustrates the character "A".

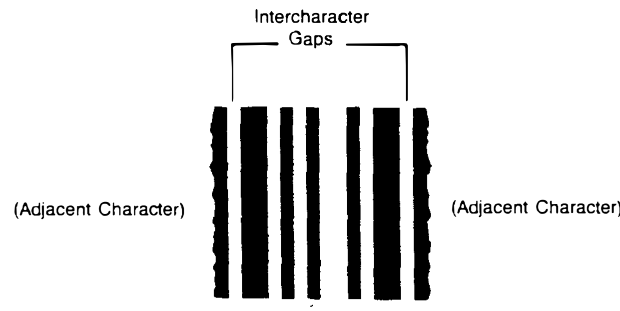

Figure 2. USS-39 "A" Character

Each bar or space can be one of two alternative widths, referred to as "wide" and "narrow". The particular pattern of wide and narrow bars determines the character being coded. In all cases, each character consists of three wide and six narrow elements.

Table 2 defines all of the USS-39 character assignments. In the table columns headed "Bars" and "Spaces", the character 1 is used to represent a wide element, and a 0 to represent a narrow element.

CHAR.	PATTERN	BARS	SPACES	CHAR.	PATTERN	BARS	SPACES
1		10001	0100	M		11000	0001
2		01001	0100	N		00101	0001
3		11000	0100	O		10100	0001
4		00101	0100	P		01100	0001
5		10100	0100	Q		00011	0001
6		01100	0100	R		10010	0001
7		00011	0100	S		01010	0001
8		10010	0100	T		00110	0001
9		01010	0100	U		10001	1000
0		00110	0100	V		01001	1000
A		10001	0010	W		11000	1000
B		01001	0010	X		00101	1000
C		11000	0010	Y		10100	1000
D		00101	0010	Z		01100	1000
E		10100	0010	-		00011	1000
F		01100	0010	.		10010	1000
G		00011	0010	SPACE		01010	1000
H		10010	0010	*		00110	1000
I		01010	0010	$		00000	1110
J		00110	0010	/		00000	1101
K		10001	0001	+		00000	1011
L		01001	0001	%		00000	0111

*Denotes the special start/stop code character

Table 2. USS-39 Character Structure

2.2 Start and Stop Character

The start/stop character, depicted by an * above, is used to identify the leading and trailing ends of the bar code symbol. It is a unique character, which allows USS-39 symbols to be scanned bidirectionally.

2.3 Quiet Zone

The quiet zone is an area clear and free of all printing preceding the start character and following the stop character.

2.4 Check Character

A special check character is not required by USS-39. An optional check character scheme is defined in Appendix C.3.

2.5 Transmitted Data

When decoding USS-39 symbols, a bar code reader does not transmit the start/stop character. All data characters are transmitted. The check character (if present) may be transmitted. The 36 two-character labels in which both characters are symbols from the set (+, -, ., /, %, $) are reserved for use as control labels. Readers may be programmed to respond to these symbols by performing system-specific functions, and the literal translation of these symbols will not be transmitted. (See Appendix C for special handling of certain characters in optional full ASCII mode.)

3.0 Dimensions and Tolerances

3.1 Measurement Conditions

Implicit in the measurement of element width is the measurement which locates the boundary between the light and dark elements of the symbol. In order to allow for measurements to be made in the presence of edge roughness, spots and voids, the boundary is defined as the position of the center of a circular sample aperture no larger than 0.8X when the apparent reflectance of the sample viewed through the aperture is exactly half way between the maximum and minimum reflectance values obtained by that aperture on the adjacent bar and space. X is the width of a narrow element.

3.2 Physical Dimensions

The nominal width of a narrow element is referred to as the "X Dimension", or simply "X". The minimum standard X dimension for USS-39 is 0.0075 inch (0.191mm). The X dimension shall remain constant throughout the symbol.

See Appendix F for considerations relevant to closed system applications.

The ratio of the nominal wide element width to the nominal narrow element width (wide to narrow ratio) is designated "N". The value of N must remain constant throughout any given USS-39 symbol. For symbols with X dimension of 0.020 inch (0.508 mm) or larger, the allowable range for N is 2.0 to 3.0. For symbols with X dimension smaller than 0.020 inch (0.508 mm), the allowable range for N is 2.2 to 3.0.

Within the USS-39 symbol, the nominal width of the intercharacter spaces shall be:

Minimum Width - 1X-t; where t is the printing tolerance for a particular value of X and N

Maximum Width - a. 5.3X for values of X less than 0.010 inches (0.250 mm)
b. 3X or 0.053 inches (1.35 mm), whichever is greater for values of X greater to or equal to 0.010 inches (0.25 mm)

See Appendix F for considerations relevant to closed system applications.

For general application, the minimum bar height should be 0.25 inch (6.35 mm) or 15 percent of the symbol length, whichever is greater.

The minimum quiet zone width is 10 times the X dimension (10X) or 0.10 inch (2.54 mm), whichever is greater. For optimum hand scanning, the quiet zone should be at least 0.25 inch (6.35 mm).

3.3 Symbol Length

The length L of a USS-39 symbol, including quiet zones, is given by:

$$L = I(1 + C) + (C + 2)(6X + 3NX) + 2Q$$

where:

Q = Width of quiet zone
I = Width of intercharacter gap
C = Number of data message characters (including check character if used)
X = X dimension
N = Wide to narrow ratio

3.4 Dimensional Tolerances

The various processes used to prepare bar code symbols have a limited capacity to produce the bars and spaces with widths which precisely match the ideal symbol. Bar code reading systems are designed to read imperfect symbols to the extent that practical algorithms permit. Appendix B describes the reference decode algorithm used in the derivation of the error tolerances given below.

The tolerance, or maximum allowable element width deviation from nominal, is constant for any given symbol and is designated "t". This tolerance is defined as:

$$t = \pm 4/27\,(N - 2/3)\,X$$

N is the wide to narrow ratio, and X is the nominal narrow width or X dimension as defined above.

Table 3 below lists the tolerance values for some common nominal dimensions.

Nominal Width of Narrow Elements (X) in inches (mm)	Wide to Narrow Ratio (N)	Density in characters per inch	Element Width Tolerances (t) in inches (mm)
0.0075 (0.191)	2.2	9.8	±0.0017 (0.0432)
0.020 (0.508)	2.0	3.8	±0.0040 (0.102)
0.030 (0.762)	2.5	2.3	±0.0081 (0.206)
0.040 (1.02)	3.0	1.6	±0.014 (0.356)

Table 3
Tolerance Values

Figure 3 shows tolerance as a function of X dimension and wide to narrow ratio (N).

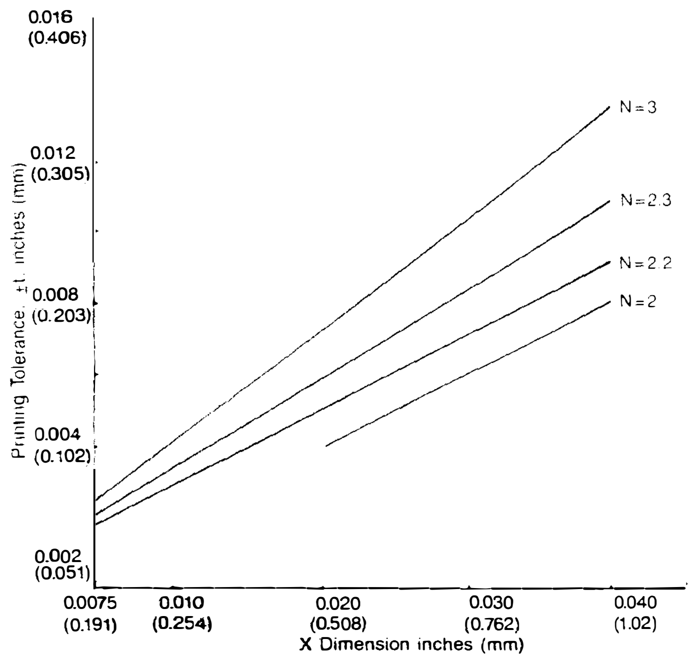

Figure 3 USS-39 Dimensional Tolerances

These errors should not accumulate within a single character. The sum of the widths of any number of adjacent elements within any character shall not deviate from nominal by more than 2t.

4.0 Optical Specification

4.1 Introduction and Summary

The optical characteristics of the printed bar code symbols can vary substantially because of the varied processes which may be used to produce them. It is necessary that certain optical properties be maintained within acceptable limits if the reading process is to be reliable. In particular, this specification describes the reflectance characteristics of the bar and space elements within the symbol and the spectral band to be used by the reflectance measurement equipment.

The reflectance specifications have been designed so that a sufficiently discernable difference in reflectance exists between spaces and bars. This difference must be at least 37.5 percentage points for symbols with an X dimension of less than 40 mils (1.02 mm) and at least 20 percentage points for symbols with an X dimension of 40 mils (1.02 mm) or larger. Bar reflectance must always be less than 30 percent and space reflectance more than 25 percent.

Finally, this specification limits the amount of noise, that is, the reflectance variation, which can be tolerated within a bar or space and across the entire symbol. Noise can be caused by such printing defects as spots and voids, non-uniformity in the substrate material, or the show-through of patterns under a substrate which is not adequately opaque. Reflectance variation within bars or spaces must be limited to be no greater than one-quarter the minimum reflectance difference between bars and spaces. In other words, the noise within one symbol element cannot exceed 25 percent of the minimum signal amplitude obtained between bars and spaces. Across an entire symbol, the reflectance of either the set of bars or the set of spaces can not vary any more than one-half the minimum reflectance difference between bars and spaces. The combined noise from all optical sources must not cause these limits to be exceeded.

A more detailed presentation of the optical specification is given in the sections which follow. Measurements have been defined in a manner which in many respects parallels the operation of most bar code reading systems.

4.2 Measurement Conditions

4.2.1 Spectral Band

All AIM USS symbols must satisfy the minimum reflectance specification cited below for the spectral band centered at 633 nanometres in the visible spectrum. Measurements shall be made with a system having its peak response at 633 nanometres ±5 percent and having a half-power band width no greater than 120 nanometres (in which there are no secondary peaks). Among possible source-filter-photodetector combinations which can be used are those employing a He-Ne laser, appropriate red LED's or alternatively the CIE Source A illuminant (incandescent source) along with an S-4 response photodetector and a Wratten 26 red filter.

Appendix F includes a discussion of systems which are designed to operate in spectral bands other than the 633 nanometre band.

4.2.2 Diffuse Reflectance Measurements of Bars and Spaces

The diffuse reflectance of a surface is defined to be the ratio of the diffusely reflected radiation from the surface to that reflected from a specially prepared Magnesium Oxide or Barium Sulfate standard that is measured under the same illuminating and viewing conditions. Standard viewing conditions require the viewing and illuminating axes to be separated by 45 degrees with one of the axes positioned normal to the sample surface. In order to reject specular reflections, the aperture of the viewing and illuminating system should subtend an angle no greater than 15 degrees measured from the sample surface.

Either the light source or the receiver must restrict the sample field to an area equal to a circle of diameter 0.8X, where X is the width of a narrow element of the bar code, or as specified in an application standard. The other optical path must have a field of view on the sample large enough to include a circle of diameter 8X or more, centered on the 0.8X diameter circle defined above. The two alternatives represent either flood illumination with sample area viewing defined at the receiver or illuminant sampling of the area as with a focused light source and wide area viewing.

4.3 Essential Bar Code Measurements

4.3.1 Measurement Conditions

The reflectance specifications given below are based upon signal-to-noise requirements for the reliable decoding of a symbol by a bar code reader. The *signal* is the reflectance difference between a bar and a space. *Noise* is any variation in reflectance caused by gradations in the ink or substrate material. Spots and voids in the symbol and the *show-through* of a pattern underlying a label with low opacity can also contribute to noise in bar and space reflectance values. It is essential, therefore, that a symbol be sampled adequately and that conditions under which an underlying dark surface or pattern may affect the symbol quality be included in the measurement process. The net effect of all noise contributing factors must not cause the symbol reflectance measurements to fall outside of the stated specifications.

4.3.2 Reflectance Measurements

Figure 4 depicts the bar code reflectance measurement process and in graphical form shows the key measurement parameters required to describe the quality of the bar code symbol. Figure 4a indicates the position of the sample aperture on a bar code image in which reflectance measurements are made. Note that all sample reflectance measurements are made with the sampling aperture confined within the area of a space or bar. No reflectance measurements are made with the aperture positioned across the edge between a bar and space as defined in Section 3.1 above. A plot of the reflectance measurements is shown in Figure 4b along with annotations describing the essential bar code reflectance parameters. On the left are indicated the maximum space reflectance R_S (MAX), the minimum space reflectance R_S (MIN), the maximum bar reflectance R_B (MAX), and the minimum bar reflectance R_B (MIN), obtained over all samples. On the right are indicated the ranges of reflectance ΔR_E obtained from a typical space and a typical bar element.

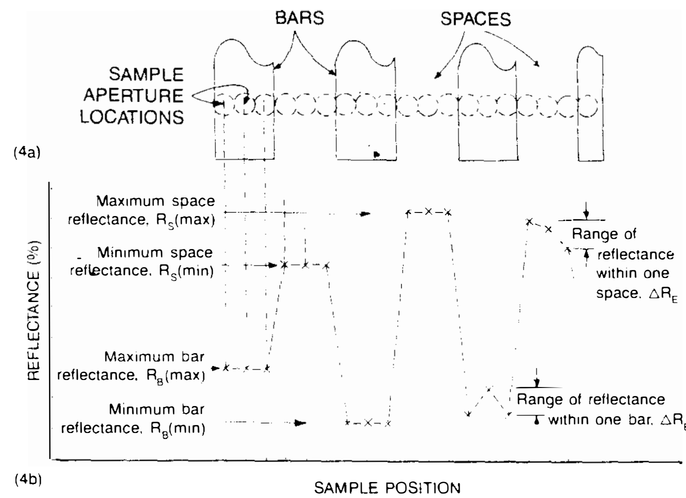

Figure 4. Bar Code Reflectance Measurements

4.4 Reflectance Specifications

The reflectance characteristics of AIM USS symbols must comply with the following specification:

4.4.1 Maximum Bar Reflectance (R_B)

R_B (MAX) < 30 percent

4.4.2 Minimum Space Reflectance (R_S)

R_S (MIN) > 25 percent

4.4.3 Minimum Bar-Space Reflectance Difference, MRD

The difference in reflectivity between the lightest bar and the darkest space is called MRD (Minimum Reflectance Difference). In other words, MRD = R_S(MIN) – R_B(MAX). The minimum value of MRD is:

MRD ≥ 37.5 percent for X < 0.040 inches (1.02 mm)
MRD ≥ 20 percent for X ≥ 0.040 inches (1.02 mm)

The special provisions for symbols with X ≥ .040 inches (1.02 mm) have been made in order to accommodate the printing of lower density labels on darker backgrounds.

4.4.4 Element Uniformity

4.4.4.1 Maximum variation in reflectance of a single element, ΔR_E (MAX)

The maximum permissible variation in the reflectance measurements made across one bar or space element cannot exceed one quarter of the MRD defined in 4.4.3;

ΔR_E **(MAX) across one element $\leq$ 0.25 MRD**

4.4.4.2 Maximum variation in reflectance of spaces across entire symbol, ΔR_S (MAX)

The maximum permissible variation in the reflectance across all spaces is one-half of the minimum bar-space reflectance difference as defined in 4.4.3;

$\Delta R_S(MAX) = R_S(MAX) - R_S(MIN) \leq 0.5\,MRD$

4.4.4.3 Maximum variation in the reflectance of bars across entire symbol, ΔR_B (MAX)

The maximum permissible variation in the reflectance across all bars is one-half the actual measured value of the minimum bar-space reflectance difference as defined in 4.4.3 above;

$\Delta R_B(MAX) = R_B(MAX) - R_B(MIN) \leq 0.5\,MRD$