Guidelines for Producing Quality Symbols

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Disclaimer

IAPMO

In this publication, the letters "U.P.C." are used solely as an abbreviation for the "Universal Product Code" which is a product identification system. They do not refer to the UPC, which is a federally registered certification mark of the International Association of Plumbing and Mechanical Officials (IAPMO) to certify compliance with a Uniform Plumbing Code as authorized by IAPMO.

About GS1 US

GS1 US, Inc. is a not-for-profit organization dedicated to the adoption and implementation of standards-based, global supply chain solutions. GS1 US operates subsidiaries EPCglobal North America™, RosettaNet, and 1SYNC™. GS1 US manages the United Nations Standard Products and Services Code® (UNSPSC®) for the UN Development Programme. EPCglobal Inc™ is a joint venture of GS1 US and GS1®. GS1 US-based solutions, including business processes, XML standards, EDI transaction sets, and the bar code identification standards of the GS1 System are currently used by more than one million companies worldwide. For more information, visit www.gs1us.org

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1 Introduction

At the onset of the GS1 System, only the EAN/UPC symbology was used by GS1. Grocers used the symbology as a key to unlock stored information about the products they were selling and to make the process of doing so more efficient. Today, over 1 million product manufacturers/labelers in every corner of the world use the GS1 System to unlock information relating to product updates, product promotions, product regulations, category management, inventory management, and more. This unique system of identification has expanded beyond grocery to general merchandise, apparel, food service, publishing, government, healthcare, and many other industrial and commercial sectors.

As the GS1 System grew and matured, GS1 members wanted to use their GS1 Company Prefix to identify product configurations, shipments, company assets, physical locations, product attributes, and much more. In order to accommodate these expanded applications, GS1 specified the use of new symbologies. This guideline provides a better understanding of the GS1 System specified symbologies.

1.1 Overview

The symbols illustrated in the following section are the symbols specified for use within the GS1 System. Each is used for different applications. This guideline reviews each of the symbols along with the specifications regarding the specific applications. Following the advice on the specific symbols, general advice is given regarding the production of bar code symbols.

1.1.1 GS1 Specified Symbols

UPC-A encodes GTIN®-12

6 14141 99999 6

EAN-13 encodes GTIN-13

5 425000 033332

EAN-8 encodes GTIN-8

9501 0502

UPC-E encodes special GTIN-12

0 402931 1

ITF-14 encodes GTIN-14

20614141999990

GS1-128 encodes all GS1 data structures (up to 48 alphanumeric characters)

(01)70614141999995(17)100101(10)ABC123

GS1 DataBar™ (RSS) Omnidirectional Expanded encodes all GS1 data structures (up to 74 alphanumeric characters)

(01)70614141999995(17)100101(10)ABC123

GS1 DataBar Expanded Stacked - GS1 data structures (up to 74 alphanumeric characters)

(01)70614141999995(17)100101(10)ABC123

GS1 DataBar encodes GTIN-14

(01) 0 6141419 99996 8

GS1 DataBar Stacked Truncated encodes GTIN-14

(01) 0 6141419 99996 8

GS1 DataBar Limited encodes GTIN-14 (Indicators 0 and 1 only)

(01) 0 6141419 99996 8

GS1 DataBar Stacked encodes GTIN-14

(01) 0 6141419 99996 8

GS1 DataBar Stacked Omnidirectional encodes GTIN-14

(01) 0 6141419 99996 8

GS1 Data Matrix encodes all GS1 data structures (special applications only)

1.2 Who Should Use This Guideline

This document offers guidelines for those that:

- Write bar code symbol specifications
- Design bar codes
- Prepare bar codes for production in prepress
- Act as a quality manager or plant manager for a printing company

2 Scope

2.1 Purpose

This document is divided into three subsections designed to offer guidance on the production of quality bar codes:

- Symbology advice
- Printing the symbol
- Symbol quality

2.2 Applicability

This guideline applies to the production and appropriate use of GS1 symbols.

3 References

3.1 Normative References

The standards listed below are referenced in this guideline. The relevant provisions contained in the referenced specifications constitute provisions of the guideline.

- *GS1 General Specifications* – Available in the Solutions Center through the GS1 US website at www.gs1us.org/solutionscenter

3.2 Informative References

The GS1 US website located at www.gs1us.org

4 Terms and Definitions

Term	Definition
Check Digit	A digit calculated from the other digits of an element string, used to check that the data has been correctly composed or correctly keypunched.
Concatenation	This refers to the joining and encoding of multiple data strings identified with Application Identifiers into a single bar code.
Element	Either a bar or a space. Bar codes usually have a set number of element widths, for example a bar code might have 2 element widths of 1x and 2.5x, meaning that the bars and spaces can be as wide as the narrowest bar or space or two and a half times the width of the narrowest bar or space.
GS1®	GS1, based in Brussels, Belgium, is comprised of global GS1 Member Organizations and manages the GS1 System and Global Standards Management Process.
GS1 US™	GS1 US is a not-for-profit organization dedicated to the adoption and implementation of standards-based, global supply chain solutions. Under its auspices, GS1 US operates four divisions, 1SYNC, BarCodes and eCom, EPCglobal North America, and RosettaNet. GS1 US manages the United Nations Standard Products and Services Code for the United Nations Development Programme. GS1 US-based solutions, including business processes, business message standards using Extensible Markup Language, Electronic Data Interchange transaction sets, and the bar code identification standards of the GS1 System are currently used by more than one million member companies worldwide. GS1 US is headquartered in Lawrenceville, NJ USA.
GTIN®	Global Trade Item Number®
Module	Related to X-dimension in that one module equals 1x.
Symbol Character	A group of bars and spaces in a symbol that is decoded as a single unit. It may represent an individual digit, letter, punctuation mark, control indicator, or multiple data characters.
Symbol Quality Specification	This is noted as the minimum symbol grade/measuring aperture/measuring wavelength. For example, 1.5/06/670 indicates a minimum symbol grade of 1.5, or C, a measuring aperture of 6 mils and a measuring light wavelength of 670 ±10 nanometers.
X-dimension	The term used to refer to the size of a bar code. Sometimes called the Narrow Bar Width, X= one thousandth of an inch (or 1 mil) and describes the width of the narrowest bar or space in a bar code.

5 Symbology Advice

5.1 EAN/UPC Symbology

The EAN/UPC symbology includes the UPC-A, UPC-E, EAN-13, and EAN-8 bar code symbols. The primary application for this symbology is retail point-of-sale (POS) scanning. These symbols allow numeric encodation only.

Each EAN/UPC symbol character is made up of four elements and has seven modules. In other words, each number encoded is represented by two bars and two spaces, and the total width of those two bars and two spaces is seven times (7x) the width of the narrowest bar or space.

EAN/UPC symbol size is measured by print magnification. A standard size EAN/UPC symbol has a print magnification of 100%. A 100% symbol is a 13 mil symbol, meaning that the narrowest bar / space is 0.013 inches wide. This 0.013 inches is the narrow bar width or X-dimension. The smallest allowable print magnification is 80% or 10.4 mils, and the largest print magnification is 200% or 26 mils.

NOTE: Some thermal style and laser style on demand printers cannot achieve an 80% magnification because of the print head density. As a result, an allowance for on demand printing equipment exists. You may print the EAN/UPC symbols at 75% magnification using on demand printing equipment.

The data string is completed by a Check Digit.

The non-data overhead (those items that are not data but take up “room” in a symbol) are the left, right, and center guard bars, excluding the Check Digit and Quiet Zones.

The symbol is omnidirectionally readable as a result of having each of the halves “over-square” meaning that the bars and spaces are higher than the segment is wide. Each segment can be read separately and “stitched” together. The symbol may not be truncated, which means the length of the bars may not be vertically shortened.

5.2 UPC-A

Prior to January 1, 2005, the predominate symbology for POS in North America was the UPC-A bar code symbol.

UPC-A encodes the GTIN-12 data structure.

At 100% print magnification, the minimum symbol height is 1.00 inch.

The minimum Quiet Zone is 9x.

The symbol can be divided into two segments, which are defined by the center guard bars. The left side symbol characters have odd parity and the right side symbol characters have even parity. The following table explains that each dark module is a “1” and each light module is a “0” where you sum the total for each character.

5.2.1 UPC-A Symbol Description

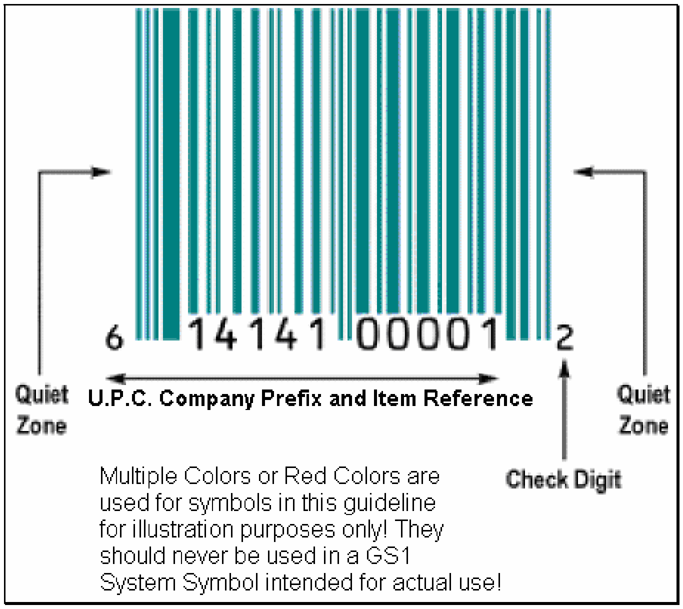

Figure 5.1 – The GTIN-12 ID number and the UPC-A symbol

The 12 digits appear below the bars and spaces in a 1-5-5-1 or a 6-6 format. They must be printed in a clearly legible font, such as Optical Character Recognition-B (OCR-B). The first 11 digits contain the U.P.C. Company Prefix and Item Reference. The last digit is the Check Digit. The UPC-A symbol requires an area free of printing on the left and right of the symbol that is nine times the width of the narrowest bar. These areas are referred to as Quiet Zones (light margins). The Quiet Zones for Add-On Symbols (used on periodicals and paperback books) shall not encroach on the right-hand Quiet Zone of the main symbol or exceed 12 times the narrow bar width.

Digit	Left Symbol Character (odd parity)	Right Symbol Character (even parity)
0	0001101	1110010
1	0011001	1100110
2	0010011	1101100
3	0111101	1000010
4	0100011	1011100
5	0110001	1001110
6	0101111	1010000
7	0111011	1000100
8	0110111	1001000
9	0001011	1110100

Figure 5.2 – UPC-A character encodation

5.3 EAN-13

Prior to January 1, 2005, the predominate symbology for POS outside North America was the EAN-13 bar code symbol.

EAN-13 encodes the GTIN-13 data structure.

At 100% print magnification, the minimum symbol height is 1.00 inch.

The symbol can divided into two segments, which are defined by the center guard bars.

The minimum left Quiet Zone is 11x and the minimum right Quiet Zone is 7x.

5.3.1 EAN-13 Bar Code Symbol Description

The EAN-13 symbol is almost identical to the UPC-A symbol. The differences include:

- The EAN-13 symbol Quiet Zones are 11 times the module width on the left and seven times the module width on the right. A small carrot-shaped mark (>) is recommended to indicate the width of the right EAN-13 Quiet Zone.
- There are 13 data characters printed beneath the symbol in a 1-6-6 format.
- In the UPC-A symbol, the first and last symbol characters are of reduced size. In the EAN-13 symbol, they are the same height as the other symbol characters.

The UPC-A symbol actually encodes 13 digits. The first digit (leftmost) is always a zero. However, only 12 digits are printed beneath the UPC-A symbol for Human Readable Interpretation.

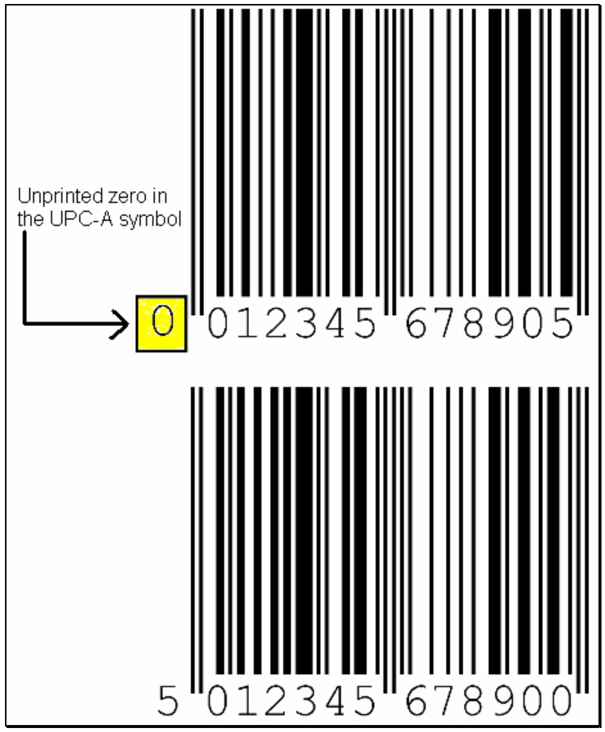

Figure 5.3 – UPC-A and EAN-13 symbols

The first digit is not encoded into symbol characters like the other 12 digits. It is encoded in a method called variable parity encodation. This means the first digit determines the way data characters are represented in bars and spaces in the left half of the symbol. The following graphic shows how digit 5 is encoded in the left half of the UPC-A symbol and how it is encoded in the left half of some EAN-13 symbols

.

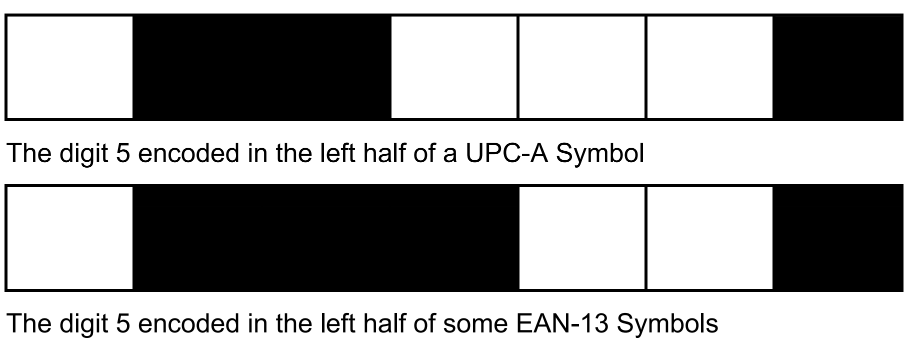

Figure 5.4 – Variable encodation

When the scanner decodes the symbol, it uses the differences in the way the symbol characters are encoded in the left half of the symbol to determine the first digit. For a more technical description of this process, or general information about EAN symbols, refer to the *GS1 General Specifications*.

	Number sets used for each position on left half of symbol					
Data Digit	**1**	**2**	**3**	**4**	**5**	**6**
0	A	A	A	A	A	A
1	A	A	B	A	B	B
2	A	A	B	B	A	B
3	A	A	B	B	B	A
4	A	B	A	A	B	B
5	A	B	B	A	A	B
6	A	B	B	B	A	A
7	A	B	A	B	A	B
8	A	B	A	B	B	A
9	A	B	B	A	B	A

Figure 5.5 – Number set used as a result of the first digit of a GTIN-12 or GTIN-13

Data Digit	Number set A	Number set B	Number set C
0	0001101	0100111	1110010
1	0011001	0110011	1100110
2	0010011	0011011	1101100
3	0111101	0100001	1000010
4	0100011	0011101	1011100
5	0110001	0111001	1001110
6	0101111	0000101	1010000
7	0111011	0010001	1000100
8	0110111	0001001	1001000
9	0001011	0010111	1110100

Figure 5.6 – How digits are represented by bars (1) and spaces (0) in each number set

NOTE: The EAN-13 symbol should not be used to carry (encode) the GTIN-12 (UPC-A) ID number, and the EAN-8 symbol should not be used to carry the zero-suppressed GTIN-12 (UPC-A) ID number.

5.4 EAN-8

EAN-8 is restricted in use to those small items that cannot fit a UPC-A or EAN-13.

At 100% print magnification, the minimum symbol height is 0.80 inches.

EAN-8 encodes the GTIN-8 data structure.

In addition to the 7x Quiet Zone at either end of the symbol, EAN-8 requires a 1x clear area at the top of the bars.

5.5 UPC-E

UPC-E is restricted in use to those small items that cannot fit a UPC-A.

UPC-E encodes a specially constructed GTIN-12, and is available only to certain U.P.C. Company Prefixes. The GTIN-12 always begins with a zero.

The minimum left Quiet Zone is 9x. The minimum right Quiet Zone is 7x, and there is a minimum 1x Quiet Zone at the top of the symbol.

5.5.1 UPC-E Symbol Description

Figure 5.7 – UPC-E symbol

This symbol is much narrower than the UPC-A symbol. Instead of encoding 12 digits into the bars and spaces, it encodes only six. The first and last data characters shown beneath the symbol are not encoded in the bars and spaces. The first digit in the symbol is always the zero in the leftmost position of the UPC-A ID number. The last digit, the Check Digit of the UPC-A, is encoded using a variable parity encodation technique similar to that described in the EAN-13 symbol. Zeroes are then removed from the remaining 10 digits of the UPC-A ID number to form the six-digit number encoded in the bars and spaces. The Quiet Zones for UPC-E symbols are 9x on the left and 7x on the right.

5.6 ITF-14

ITF-14 is an Interleaved 2 of 5 defined for use by the GS1 System.

This symbol encodes the GTIN-14 data structure.

ITF-14 has two element widths – 1x and a target of 2.5x. Since it only has two element widths, it is ideal for direct print on corrugate. It is the only symbology allowed for direct print on corrugate by the GS1 System.

Each symbol character is made up of five elements - 2 wide and 3 narrow.

The symbol requires a 10x left and right Quiet Zone.

The GS1 System requires the use of bearer bars. When printed using the printing plate method, the bars must be on all four sides (forming a box) with a minimum 0.19 inches width. When printed using a non-printing plate method, the bars need only be printed on top and bottom with a minimum width of 2x or two times the narrow bar width.

The allowed print densities include:

- Minimum - 9.84 mils (effectively 10 mils)

- Nominal - 19.5 mils (effectively 20 mils)
- Maximum - 40 mils

When printed at or larger than 25 mils, ITF-14 has an allowable minimum symbol grade of 0.5.

5.6.1 ITF-14 Start Character

All ITF symbols have the same start pattern as illustrated in the following graphic. The start pattern is not displayed in Human Readable Interpretation above or below the symbol, but is encoded in the symbol and decoded by the scanner.

Figure 5.8 – ITF-14 Start Character

5.6.2 ITF-14 Symbol Characters

ITF-14 symbols have a fairly simple structure when compared to EAN/UPC and GS1-128 symbols. There are only two element widths for the ITF-14 symbol, where EAN/UPC and GS1-128 symbols have four different element widths.

The ITF-14 symbol only encodes pairs of numeric data characters. The number in the first position of the pair (8) is encoded into five bar elements. The number in the second position of the pair (3) is encoded into five space elements. Two out of the five bar elements are wide and two out of the five space elements are wide, hence the name "2-of-5." Then the bars and spaces are interleaved to form the double-density numeric symbol character, hence the name "Interleaved 2-of-5."

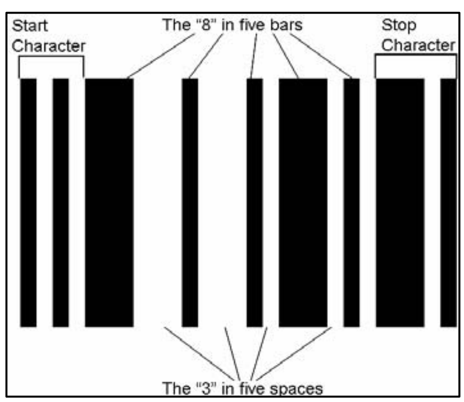

Figure 5.9 – ITF-14 encodation of a two-digit pair

The 14-digit GTIN-14 is encoded into seven ITF-14 symbol characters. This means there are 35 bars and 35 spaces between the Start and Stop Characters for the GTIN-14 as illustrated in the following graphic.

10614141999993

Figure 5.10 – ITF-14 data characters encodation into symbol characters

5.6.3 ITF-14 Stop Character

All ITF symbols have the same stop pattern as illustrated in the following graphic. The stop pattern is not displayed in Human Readable Interpretation above or below the symbol, but is encoded in the symbol and decoded by the scanner.

10614141999993

Figure 5.11 – ITF-14 Stop Character

5.6.4 Quiet Zones (Light Margins)

All ITF-14 symbols have a Quiet Zone on the left and right side. The Quiet Zone widths are equal to ten times the width of the X-dimension (10x).

5.6.5 The X-dimension and Bar Width Ratio

ITF-14 symbols are used to encode the GTIN-14 ID number. The GS1 System specifies a nominal X-dimension of 20 mils. There is an allowable magnification range of between 50% (10 mils) and 200% (40 mils). Note that 20 mils is the minimum for packages scanned in a general distribution environment. There are only two widths for the bars and spaces in the ITF-14 symbol. Since the ITF-14 symbol only has two element widths, some customers may specify a bar width ratio between the wide and narrow bars. The GS1 System specifies a nominal bar width ratio of 2.5:1. For example, if the narrow bar element is 40 mils wide, the wide bar should be 2.5 times wider, or 100 mils. The allowable range of ratios for ITF-14 symbols used by the GS1 System is 2.25:1 to 3:1.

5.6.6 Bearer Bars

The GS1 System specifies that bearer bars surround the ITF-14 symbol to:

- Reduce the probability of misreads when the scanning beam is skewed in relation to the symbol.
- Provide printing plate support at critical areas when printing directly on packaging materials, such as corrugated, with conventional wet ink printing processes.

When the symbol is printed directly on the packaging material using a printing plate method, the GS1 System specifies that the bearer bar completely surround the symbol, as shown in the following graphic.

10614141999993

Figure 5.12 – ITF-14 symbol bearer bars

When the symbol is printed indirectly (such as on labels or tags) or with a non-contact method (such as ink-jet), the bearer bars need only appear at the top and bottom of the bar code bars (butting directly against the top and bottom of the bars).

5.7 GS1-128

GS1-128 is a sub-set of the general symbology Code 128, and allows alphanumeric encodation.

This symbol encodes all GS1 data, and multiple data structures by means of concatenation.

Each symbol character is made up of six elements, that is, three bars and three spaces, and there are 11 modules per symbol character.

The maximum symbol width is 6.5 inches (including Quiet Zones).

The Function Code 1 (FNC1) character is used as a group separator to separate variable length fields and as an Indicator of GS1 data.

The symbol requires a 10x left and right Quiet Zone.

The encoding of an even number of symbol characters is the most efficient encoding when encoding all numeric data.

The allowable print densities are:

- Minimum - 9.84 mils (effectively 10 mils)
- Nominal - 19.5 mils (effectively 20 mils)
- Maximum - 40 mils

5.7.1 Code 128 Code Sets A, B, and C

Unlike the all-numeric EAN/UPC and ITF-14 symbols, Code 128 provides for numeric, upper- and lower-case alphabetic characters, punctuation, special function, and control data characters. This is accomplished by assigning three possible meanings for each symbol character based on three code sets, Code Sets A, B, and C.

- Code set A symbol characters can encode all of the standard upper-case alphanumeric keyboard characters and special characters.
- Code set B symbol characters can encode all of the standard upper- and lower-case alphanumeric keyboard characters and special characters.
- Code set C characters encode numeric-only data character pairs (00-99) into one symbol character. By encoding numeric data with twice the density, the symbol width is

reduced. This means code set C is used for all-numeric data. In addition to the double-density numeric symbol characters, code set C can encode several special characters.

For more information, a detailed list of each symbol character code set can be found in the *GS1 General Specifications*.

5.7.2 GS1-128 Start Codes

GS1-128 is a subset of Code 128. This is possible because Code 128 encodes four special symbol characters referred to as function characters. The GS1-128 bar code symbol has a special double character start pattern consisting of either a Start Code A, B, or C character as the first symbol character (shown in cyan) and a Function Code 1 (FNC1) as the second symbol character (shown in magenta). This unique start code pattern identifies the symbol as a GS1-128.

The symbol below has a GS1-128 Start Code C symbol character and an FNC1 symbol character.

(420) 12345

Figure 5.13 – GS1-128 Start Character

To shift between code sets, Code 128 symbols use characters detailed in *Section 5.3.3.2* in the *GS1 General Specifications, Figure 5.3.3.2-1* (see Symbol Character Values 99, 100, and 101). The following figure illustrates a symbol that begins with a code set C start pattern (in cyan) followed by nine double-density numeric symbol characters (in magenta). It then highlights a "change to code set B" symbol character (in green). This character tells the scanner that the remaining symbol characters (AaBbCcDd) are to be decoded from code set B (in orange):

(01) 1 06 14141 99999 3 (21) AaBbCcDd

Figure 5.14 – GS1-128 with a code set change

5.7.3 Variable Length Field Separators

When multiple variable length fields are used, the fields are placed at the end of the symbol and a FNC1 symbol character is inserted between them. The first variable length field in the following graphic is shown in cyan, the FNC1 field separator is shown in magenta, and the second variable length field is shown in green.

(01) 1 06 14141 99999 3 (10) 1234 (21) 6789

Figure 5.15 – GS1-128 FNC1 field separator

5.7.4 GS1-128 Symbol Check Character

All Code 128 symbols have a Symbol Check Character that is not a part of the data input and is in addition to any Check Digits used in the data. The Symbol Check Character is not displayed in Human Readable Interpretation, but is encoded in the symbol directly before the Stop Character (shown in cyan) and decoded by the scanner as shown in the following graphic.

(420) 12345

Figure 5.16 – GS1-128 Symbol Check Character

5.7.5 GS1-1 28 Stop Characters

All GS1-128 symbols have a Stop Character as illustrated in the following graphic. The Stop Character is not displayed in Human Readable Interpretation, but is encoded in the symbol, as shown in cyan below.

(420) 12345

Figure 5.17 – GS1-128 Stop Character

5.7.6 Quiet Zones (Light Margins)

All GS1-128 symbols have a Quiet Zone on the left and right side. The Quiet Zone widths are equal to ten times the width of the X-dimension (or 10x).

5.7.7 X-dimension

The elements within the GS1-128 symbol have four different modular widths. The narrowest bar or space width is referred to as the X-dimension of the symbol. The X-dimension is the basic building block of the GS1-128 symbol in that it determines the overall output width of the symbol. The other three bar or space widths are two, three, or four times the X-dimension.

Figure 5.18 – GS1-128 symbol character modules

The first bar is one module wide; the first space is two modules wide; the second bar is four modules wide; the second space is two modules wide; the third bar is one module wide; and the third space is one module wide. The sum of the bar modules within GS1-128 symbol characters is always even, and the sum of the space modules is always odd. This allows the scanner to perform a parity check of every symbol character for added security.

5.7.8 GS1-128 Symbol Building Blocks

In order to determine how wide your GS1-128 symbol will be, all you need to know is the number of symbol characters necessary for the data. This number does not include the symbol characters that the formula in the *GS1 General Specifications* includes (e.g., the Start Character code set , FNC1, Symbol Check Character, Stop Character, and Quiet Zones). Remember, if you are encoding double-digit numeric pairs, the total number of symbol characters is one half of the total number of digits when encoded in code set C.

The formula for calculating the symbol width for a given X-dimension is detailed in the *GS1 General Specifications*, *Section 5.3.7.2*. For information on minimizing GS1-128 symbol width, refer to the *GS1 General Specifications*.

5.8 GS1 DataBar (RSS) Symbology

The GS1 DataBar symbology includes:

- GS1 DataBar Omnidirectional, GS1 DataBar Truncated, GS1 DataBar Stacked, and GS1 DataBar Stacked Omnidirectional
- GS1 DataBar Limited (limited to the use of Indicators 0 and 1)
- GS1 DataBar Expanded (encompassing GS1 DataBar Expanded and GS1 DataBar Expanded Stacked)

The allowable print densities for GS1 DataBar Omnidirectional , GS1 DataBar Stacked Omnidirectional, GS1 DataBar Expanded and GS1 DataBar Expanded Stacked (these are the symbols able to be scanned omnidirectionally) are:

- Minimum - 8 mils
- Nominal - 10.4 mils
- Maximum - 13 mils

The allowable print densities for GS1 DataBar Truncated, GS1 DataBar Stacked, and GS1 DataBar Limited are:

- Minimum - 6.7 mils
- Nominal - 8 mils
- Maximum - 16 mils

The GS1 DataBar Symbology does not require a Quiet Zone. However, the left-most module in all GS1 DataBar symbols, excluding GS1 DataBar Expanded and GS1 DataBar Expanded Stacked, is a 1x space. In GS1 DataBar Expanded and GS1 DataBar Expanded Stacked, the left-most and the right-most module is a 1x space.

GS1 DataBar Expanded and GS1 DataBar Expanded Stacked encode all GS1 data structures similar to GS1-128, and multiple data structures by means of concatenation. All other GS1 DataBar symbols encode GTIN-14.

GS1 DataBar symbols are constructed in four segments and can be stacked and separated into 2-two segment portions. GS1 DataBar Expanded is constructed in up to 22 segments allowing up to 11 rows of stacked symbol. GS1 DataBar Limited is constructed in two segments.

The Check Digit is implicit in GS1 DataBar symbols and is not encoded.

5.9 GS1 Data Matrix

The GS1 Data Matrix is specified for areas that are too small for any of the GS1 linear symbols, or for direct part marking for surfaces that are not conducive to printing or labeling. GS1 Data Matrix is 1.5 times the X-dimension of the linear symbol that would be used for the application typically.

The GS1 Data Matrix is a two dimensional, matrix symbology, as opposed to linear symbologies that are built with only vertical bars and spaces.

The GS1 System uses the ECC200 version of GS1 Data Matrix. This version is characterized by the upper right-most module being light or a space.

The GS1 Data Matrix is easily recognizable by its “L” shaped finder pattern.

The GS1 Data Matrix encodes all GS1 data structures, and multiple data structures using concatenation.

The GS1 Data Matrix employs either FNC1 or macro 05 in the first character position to signify GS1 System conformity.

6 Printing the Symbol - General Considerations

6.1 Output Resolution and Dimensional Corrections

Specifying the addressable imaging resolution for bar code symbol output is critical to providing proper dimensions for the bars and spaces. A bar code, unlike typical graphic images, is machine readable based on decoding formulas. If it is not designed (encoded) without corrections to the target size based on the addressable imaging resolution, rounding errors will occur in most cases.

When you provide a target size (magnification or X-dimension) for the symbol to the software, a new size is provided by the software to correct symbol dimensions for the image setter resolution specified. This process is called corrected magnification when applied to the original bar and space widths and corrected Bar Width Reduction (BWR) when applied to the amount of BWR. This also applies to the special EAN/UPC symbol characters 1, 2, 7, and 8 when output at higher resolutions (e.g., image setters or digital "offset" printing press).

The following table shows the corrected magnification for a nominal size (100% magnification) EAN/UPC symbol based on common addressable imaging resolutions.

Dots Per Inch (DPI)	Dots Per Millimeter	Actual Dot Width (center point to center point)		Dots Per Module Width	Module Width		Corrected Magnification
		Inch	mm		Mils	mm	
1000.00	39.37	0.0010000	0.025400	13	13.000	0.33020	100.061%
1016.00	40.00	0.0009842	0.025000	13	12.795	0.32500	98.485%
1270.00	50.00	0.0007874	0.020000	16	12.598	0.32000	96.970%
2000.00	78.74	0.0005000	0.012700	26	13.000	0.33020	100.061%
2032.00	80.00	0.0004921	0.012500	26	12.795	0.32500	98.485%
2540.00	100.00	0.0003937	0.010000	33	12.992	0.33000	100.000%
3378.20	133.00	0.0002960	0.007519	43	12.729	0.32331	97.972%
4000.00	157.48	0.0002500	0.006350	52	13.000	0.33020	100.061%

Figure 6.1 – Accurate corrected magnifications of 100% EAN/UPC symbols for image setters

NOTE: The nominal EAN/UPC symbol can be used on a module width of either 0.013 inches or 0.33 mm. In North America, the long-standing Universal Product Code (U.P.C.) specifications have set the nominal module size at 0.013 inches or 13 mils. ISO-IEC specification for EAN/UPC set the nominal module at 0.33 mm. The international metric nominal is 0.0606% smaller than the original inch-based nominal. The data in the “corrected magnification” column are based on a nominal module width of 0.33 mm.

For example, EAN/UPC symbols are built of modules. A nominal EAN/UPC symbol module measures 0.013 inches (13 mils) or 0.33 mm. Using the third example, a 1270 DPI (50 dot per mm) device creates images using dots whose center points are 0.0007874 inches (0.020 mm) apart. To create a nominal symbol module using this dot size requires 16.5 dots.

Figure 6.2 – Symbol module to image setter dot ratio before corrected magnification

When the symbol size is corrected based on the image setter's addressable imaging resolution, the software rounds the 16.5 dot wide module size to either 16 or 17 dots wide (an integer number).

Figure 6.3 – Symbol module to image setter dot ratio after corrected magnification

The 17-dot choice produces a larger than nominal symbol (103.03% magnification) and might not fit in the planned area on the package. Unless it is known that a 103% symbol will fit, use 16 dots per module. When we multiply 16 times the width of the dot (0.0007874 inches or 0.020 mm), the corrected symbol module is 12.598 mils (0.320 mm) wide, instead of the target width of 13 mils (0.33 mm). This results in a corrected magnification of 96.97%. Correcting symbol dimensions slightly to accommodate the addressable imaging resolution of your image setter is far more important to scanning performance than creating a symbol with any exact size.

Resize digital bar code files using the bar code design software package that created them and which accounted for output resolution. These specifications must not be altered at any later stage within illustration or page layout software programs. Link the digital bar code file to the output resolution attribute in some way to assure the symbol is output at the resolution specified when it was created. Using the resizing tool within illustration or page layout software packages is strongly discouraged because the resulting symbol may not scan.

6.2 Pressroom Considerations

6.2.1 Distorting for Plate Roll Circumference

In certain cases, running a symbol perpendicular to the press direction is unavoidable and requires distortion of the image in the web direction based on the specified plate roll circumference. Your bar code design software may account for this input variable in the design stage. If it does, follow the procedures offered by the software provider. If your software does not account for distortion when the symbol is created and distortion of the symbol is unavoidable, output the film at a higher resolution (e.g., 4000 DPI) to avoid reintroducing rounding errors.

6.2.2 Repositioning, Rotation, and Ungrouping

Alter symbol orientation (rotation) using the program that originated the symbol. Using the rotation tool within an illustration or page layout program is not advised because the printed symbol may not scan.

When a symbol is repositioned within illustration or page layout software packages, use caution to ensure resizing or rotation of the symbol does not occur. Avoid ungrouping individual bar, space, or Human Readable Interpretation elements within a bar code graphic file. If ungrouping occurs, a single bar or group of bars within the symbol could be moved out of position unintentionally by selecting them and dragging the mouse.

6.2.3 Previews

Certain digital bar code files create a preview within illustration or page layout software programs. If the original file is accessed as a resource element from a floppy disk and the disk is removed before being saved within the document or layout, the preview could accidentally be used for output. This results in an unsuitable imaging resolution of 72 DPI.

6.2.4 Proofing

The symbol output on an image setter at one resolution may be entirely different at another resolution or on another imaging device. Your customer needs to understand this when evaluating proofs. You need to communicate when the symbol is For Position Only (FPO) or when it can be used to accurately represent a press run. The following examples may be helpful:

- If the proof is output with a specified 6 mil Bar Width Reduction (BWR), it is representative of the final printed symbol.
- If the symbol is designed to be imaged on a 2540 DPI image setter resolution and a proof is pulled from a 300 DPI printer, significant differences in symbol quality will result.

6.2.5 Press Setup

When the work order you receive includes a bar code, check the bar code numbers on the order against the numbers beneath every symbol on the imaging tool (e.g., plate, screen, cylinder). Do not assume that every number on the imaging tool will be the same. Then, check for defects in the imaging tool and printed images. Visually inspect the imaging tool for apparent damage (e.g., nicks, plugs, or tears). If you discover an error or a defect in the imaging tool, quarantine or destroy it according to your company procedures. Never revise the numbers beneath a bar code symbol by cutting or otherwise altering the imaging tool.

6.2.6 First Piece Approval

If the imaging tool appears to be in good shape, check for an acceptable ISO symbol grade in the first piece approval process. All GS1 System symbols should receive a passing ISO symbol grade of "C" or better when using a verifier with the correct aperture and wavelength unless a subsequent application guideline overrides this requirement. An exception to the minimum “C” grade is for ITF-14 symbols directly printed on corrugate. For the ITF-14 symbol printed at 25 mils or larger (which is never expected to be scanned in a checkout lane), a minimum grade of "D" is permitted due to the capabilities of industrial scanners, which are used in a distribution or logistics scanning environment.

Although it may not be possible for all packaging materials or printing processes, the ISO grade target should be one letter grade better than the minimum. Your customer needs an ISO grade of "C" for the EAN/UPC symbol when it appears on the final filled product sold at point-of-sale.

Bettering the "C" grade at the time of printing can be helpful in overcoming any symbol quality lost due to the packaging or labeling process.

When analyzing symbol quality, attempt to simulate the final filled product or package. For example, if you are printing a white EAN/UPC symbol background on a clear plastic bag, try to find out what will be inside the bag. If it is white notebook paper this could actually boost the white background. However, if it is black jelly beans, the white may appear gray to a scanner. If simulating the package is impractical, verify the printed symbol twice, once by laying the symbol over a black background and then over a white background. The worst of the two ISO symbol grades will simulate the worst case scenario.

6.2.7 Production Run

During the production run, maintaining a clean transfer of ink, proper bar widths, and consistent symbol colors are critical to repeatable symbol quality. Consider these factors when making press adjustments and follow company procedures on production sampling.

Even if the imaging tool passes inspection, production defects are common or even expected during the press run. These would be categorized as voids in bars or spots in the spaces or Quiet Zones. These defects could be caused by factors such as cleaning the imaging tool during the run, debris being caught in an ink cell or under a doctor blade, or an imaging tool being damaged. If the defect is temporary and correctable, you may decide to flag the affected portion and continue production. If the defect cannot be corrected, use your company's procedures to make a go / no-go decision.

If prepress has made the proper Bar Width Reduction (BWR), the process of reducing the image to allow for ink spread, the symbol bars should remain within the specified width throughout the run. This relationship between the BWR in prepress is critical to quality symbol production. If the pre-production analysis is correct, a symbol of adequate size and bar width reduction is made ready for the range of print gain you will experience on press. If the BWR and minimum size are correct based on prior experience and you still have poor symbol quality, you may have a problem with press factors, such as press settings, ink metering, mounting material thickness for the imaging tool, cylinder tolerance (Total Indicated Runout or TIR), or press maintenance. You may also want to evaluate the printing substrate.

When it comes to symbol color, it is understood that in many, if not all, printing processes, the colors may vary throughout the run. This is due to changes in ink viscosity, press speed, drying temperature, ink chemistry, and other factors. Attempt to control significant color changes throughout the run. It may be wise to develop an acceptable range for the bar color and space (background) color. Starting production with a symbol of marginal contrast will produce material outside of specification with any process variation. Keep in mind that marginal contrast at the printed stage may not compensate for changes in contrast caused by the packaging process, (e.g., the black jelly beans behind the white EAN/UPC symbol background).

Finally, do not mix bar code symbols with different numbers on a roll or in a box unless specified. When bar code symbols are produced using an imaging tool (e.g., plate, screen, or cylinder) on a printing press, they will almost never be printed sequentially. If the symbols become mixed on a printed roll, they might be used on the wrong product, package, or coupon when automatically packaged or applied downstream. Unless otherwise specified, it is wise to separate symbols with different numbers into batches as they are produced and later when they are packaged and shipped. If the batches are of a size which prohibits separating them, follow company procedures to carefully identify each batch.

6.3 On Demand Print Considerations

The printing technologies used to generate bar code labels and tags include thermal, thermal transfer, laser, ion deposition, ink jet, and mechanical matrix printers. This class of devices may be separated into the two categories:

- Direct thermal and thermal transfer printers
- General purpose printers

6.3.1 Direct Thermal and Thermal Transfer Printers

Direct thermal and thermal transfer printers, under the proper conditions, are capable of generating high quality bar code symbols (typically ISO grade A or B). The printers may stand-alone or they may be integrated into an application such as a weighing and labeling system. In many cases, the user has no control over the size or placement of the bar code. Quality printing is maintained by observing the following guidelines.

Direct thermal and thermal transfer printers typically contain all of the low level software required to generate bar code symbols. This means that various symbol formats are loaded into the firmware of the printer. The bar code design software simply sends commands to address the firmware in the printer to create the symbol. These commands typically relate to data characters, symbol size, symbol orientation, and symbol placement.

Generate symbols at a corrected magnification or an X-dimension that is supported by the resolution of the specified printer. For example, the closest bar width to 13 mils (0.330 mm) a 203 DPI printer can achieve is 14.76 mils (0.375 mm). This is because each bar width is constructed with three 203 DPI that individually measure 4.92 mils (0.125 mm) wide.

Avoid direct thermal printing whenever the symbol may be exposed to direct sunlight, extreme temperatures, or have a shelf life exceeding one year. These labels fade very quickly in direct sunlight, and the background darkens at elevated temperatures. Some fading also occurs as labels age at room temperature under normal indoor lighting. As labels fade or darken, the contrast decreases so that at some point the symbol can no longer be scanned.

An example of a good application for thermal labels is in-store marking of meat and other perishable food items. Such labels need last only days or weeks under protected indoor conditions.

Consumable supplies are an important quality consideration. For best results, choose the correct combination of label and ribbon materials for the printer type and application environment. Whenever a different brand or part number of labels or ribbon is loaded on the printer, repeat the initial setup process.

6.3.2 Direct Thermal and Thermal Transfer Printer Setup

Direct thermal and thermal transfer printers require different settings for best results on different combinations of label and ribbon materials. Follow the manufacturers' recommendations for making the necessary changes and adjustments.

After any change (e.g., printed format, ribbon type, label type, print speed, or printhead heat intensity), it is advisable to print a test symbol and verify it using an ANSI/ISO-based verifier. If you are printing a long run of identical symbols, verify one to determine the symbol quality. If you are printing EAN/UPC symbols that will vary in data content, a test UPC-A symbol containing the digits **4 12785 12783 2** is recommended for the verification process.

When you verify the test symbol, expect an ANSI/ISO grade of A or B using the thermal transfer process. If these grades are not achieved, you are likely to have a problem with printer adjustments, cleanliness, or some malfunction. With some direct thermal label materials, you may only be able to produce C grade symbols. While such symbols do conform to the quality specifications, you will have less margin for process variations and degradation from handling and aging.

In addition to verification, examine the test symbol for adequate Quiet Zones, bar height, and the legibility of the Human Readable interpretation.

6.3.3 Maintaining Acceptable Quality for Thermal Printers

The quality of printed symbols tends to degrade as deposits build up on the thermal print head. Regular cleaning of the print head and guide surfaces in accordance with manufacturer's recommendations is strongly advised.

Thermal print heads eventually wear out to the point where one or more dot elements fail to heat properly. When this occurs, the printed symbols may no longer be scannable. One solution to this problem is frequent verification to assure continuing quality. Some printers can be equipped with online verification devices that indicate when a problem is detected. Although such online verifiers may not test all of the ISO print quality parameters, they can be useful for monitoring the printing process. This is particularly true after supplies replacement or printer maintenance.

An alternative method for detecting dot burnout is to print a line across the width of the symbol as indicated in the following figure. Any dot failure is immediately visible to the operator as a small break in the line.

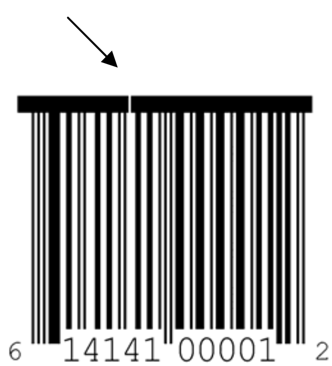

Figure 6.4 – Line detecting print head element burnout

6.3.4 General Purpose Printers

This category includes laser, desk top, ink jet, ion deposition, and mechanical matrix office printers. These devices are designed primarily for printing full size pages of text and graphics. However, they can be used to print retail tags by using pre-cut labels on page size backing paper. Some are also equipped with a continuous feed mechanism when producing symbols in large quantities.

It is more difficult for the user to create high quality bar code symbols with general purpose printers then it is with direct thermal or thermal transfer label printers. There are two causes for this difficulty. First, the printed dot size for general purpose printers is appreciably larger than the pixel dimension as shown on the right grid in the following figure. This causes the bars to be printed wider and the spaces narrower than nominal, unless the software driving the printer corrects for this distortion. Second, the software that constructs the bar code symbol may introduce dimensional errors.

Pixel (red), pixel center point grids (gray), pixel size dot (blue), enlarged dot (yellow)

Figure 6.5 – General purpose printer dot / pixel comparison

There are a wide variety of software packages for creating symbols using general purpose printers. Unfortunately, many of these packages are capable of producing symbols with totally unacceptable quality.

Generate symbols at a corrected magnification or an X-dimension that is supported by the resolution of the specified printer. For example, the closest bar width to 13 mils (0.330 mm) a 300 DPI printer can achieve is 13.12 mils (0.333 mm). This is because each bar width is constructed using four 300 DPI that individually measure 3.28 mils (0.0833 mm) wide.

Because some laser printers place pixels according to metric dimensions and others according to inch dimensions, the software designer should force the operator to select the target printer by make and model. For example, a 600 DPI laser printer may print precisely 600 DPI, or it may print 24 dots per millimeter equal to 609.6 DPI.

Specify one or more dots (pixels) of uniform Bar Width Reduction (BWR) to compensate for "oversize dot" width, which is typical of general purpose printers. For example, with a typical 300 DPI laser printer and four dots per module, best print quality is often achieved with one pixel (or dot) of BWR.

When a bar code graphic file is transferred between two parties, the printer resolution attribute should be communicated. If the printer resolution changes, recreate the bar code file. Treat the symbol as a fixed design element. <u>It should not be resized, rotated, scaled, or stretched.</u>

When a bar code graphic file is transferred between two parties, they should determine which symbol design attributes should be communicated. Consider the following list as optional attributes that can be useful in assuring symbol quality:

- Printer resolution for bar width (strongly suggested)

- Corrected magnification factor
- Corrected BWR factor

Do not alter these specifications at any later stage within illustration or page layout software programs.

These suggestions should provide you with quality symbols when the output conditions match the design attributes. The most predictable results are obtained using software packages that drive the printer directly by low level software. Often, when bar code images are passed from one software application to another, the bar code symbol may become distorted. These distorted symbols may or may not achieve passing verifier grades.

6.3.5 Initial General Purpose Printer Setup

Once you have the required software, hardware, and consumable materials in place, determine the symbol magnification and other parameters that you will be using to produce bar code labels or tags. Next, print two test UPC-A symbols with the following test symbol data:

- 0 12345 01234 1
- 6 78912 56789 0

Then, verify both test UPC-A symbols per *ISO/IEC 15416: Bar Code Print Quality Test Specifications - Linear Symbols.* It is desirable to achieve grade B or better in this initial setup. If one or both of the test symbols are below grade B, you may be able to improve the quality by changing some of the software or printer variables. At a minimum, grade C symbols are acceptable, but they leave you with minimal margin for process variations and possible degradation from handling. In addition to verification, examine the test symbols for adequate Quiet Zones, bar height, and legibility of the Human Readable Interpretation.

For small operations, the investment in an ISO-based bar code may not be justified. The alternative is to submit your test symbols to a qualified testing organization.

Finally, whenever any changes are made in software parameters, repeat the initial setup procedures.

6.3.6 Maintaining Acceptable Quality for General Purpose Printers

All printers require periodic maintenance. Laser printers, for example, not only consume toner, but also require periodic replacement of components such as drums, developers, fusers, and brushes. All of the consumable parts may be contained in a single replacement cartridge, or they may be separately installed, depending on the make and model of printer. Because bar code labels contain a higher percentage of black printing than occurs in ordinary text, fewer pages can be printed between maintenance intervals.

Visually check printed symbols for consistent appearance and verify them whenever they appear doubtful. Symbol verification, whether conducted on-site or consulted, can be an effective tool for maintaining quality within a conscientiously applied program of quality assurance. Employ verification as a quality sampling technique, particularly after any part replacement or printer maintenance.

6.4 Symbol Placement

When discussing symbol location, we are referring to the symbol placement on the design. When assigning symbol placement, consider the packaging process. Consult the packaging engineer to make sure the symbol will not be obscured or damaged (e.g., over a carton edge, beneath a carton fold, beneath a package flap, or covered by another packaging layer). To determine the proper location for GS1 System symbols, see *Section 6* of the *GS1 General Specifications.* In general terms, EAN/UPC symbols for consumer trade items are placed in the lower right quadrant of the rear of a package.

After determining the proper placement, consult the printing company before assigning the symbol rotation. This is because many printing processes require bar codes to be printed in a specific orientation to the feed direction of the web or sheet.

If possible, when using flexographic printing, the bars should run parallel to the press web direction or in the picket fence orientation. If the bars are required to run perpendicular to the press direction or in the ladder orientation, try to avoid distorting the symbol for the plate roll circumference. This lack of distortion alters the overall width of the symbol, but provides dimensional integrity. When using either silk screen or rotogravure printing processes, align the symbol parallel to the cell structure on the screen or gravure plate cylinder to provide the smoothest bar edge possible.

7 Symbol Quality

7.1 Symbol Color

The optimum color combination for a bar code symbol is black bars with a white background (spaces and Quiet Zones). If you want to use other colors, the following may help you in choosing satisfactory colors:

- GS1 System bar code symbols require dark colors for bars (e.g., black, dark blue, dark brown, or dark green).
- The bars should always consist of a single line color and should never be printed by multiple imaging tools (e.g., plate, screen, or cylinder).
- GS1 System bar code symbols require light backgrounds for the Quiet Zones and spaces (e.g., white). In addition to light backgrounds, "reddish" colors may also be used. If you have ever been in a darkroom with red lighting and tried to read red copy, you know it can virtually disappear. This is also true of similar colors such as orange, pink, peach, and light yellows. Given the fact that most bar code scanners use a red light source, you can see why these colors may be suitable for backgrounds, but should be avoided for bars.
- In many cases, the symbol background is not printed. It is the color of the substrate that is being printed. If the symbol background is printed beneath the bars, the background should be printed as solid line colors. If you use multiple layers of ink to increase the background opacity, each layer should be printed as a solid. If you use a fine screen to deliver more ink to the substrate, be sure there are no voids in the print caused by the screen not adequately filling in.

GS1 does not offer a list of acceptable colors for bars and spaces. This is because of the wide variety of inks, dyes, and substrates with varied properties that are used and varied ink transfer processes that are employed. The *GS1 US Symbol Contrast Gauge* (available in the GS1 US Product Catalog online at www.gs1us.org) provides an easy and effective way to evaluate your design contrast if it approximates the final product.

In many cases, the designer is involved in the specification of the printing material characteristics such as matte, gloss, color, or texture. The printer may then submit sample materials for evaluation and/or approval. Whenever these decisions are made, consider the bar code symbol quality. The following questions provide some examples:

- Will a fluorescent, metallic, translucent, or transparent material be overprinted to create the symbol background? If so, will the ink opacity be sufficient for symbol contrast?
- Will an overprint varnish or laminate be used? If so, will it interfere with symbol scanning?
- Will the material be pitted or textured to a degree that could create voids in the bars or spots in the background spaces?

7.2 Symbol Quality Parameters

ISO/IEC 15416 Bar Code Print Quality Test Specifications for Linear Symbols describes a method for assessing the quality of bar code symbols after they are printed. The ISO method differs from "traditional" measurement or visual inspection methods because it uses a special verifier to analyze the symbol. An ISO-based verifier looks at the symbol in the way a scanner does, but goes further by grading the symbol's quality. The GS1 System utilizes the ISO/IEC method, but specify the minimum grade necessary for every GS1 System symbol depending on which symbol is used, where it is used, or what identification number it is carrying. In addition to the minimum grade, GS1 System also specifies the verifier aperture width and wavelength. The print quality specifications for GS1 System symbols are outlined in the following table. The notation for the specification for, say, EAN/UPC symbols would read 1.5/06/670.

Symbology	Application	ISO (ANSI) Symbol Grade	Aperture	Wavelength
EAN/UPC	All	1.5 (C)	6 mils	670 nm +/-10
GS1-128	Extended Coupon Code	1.5 (C)	6 mils	670 nm +/-10
GS1-128	All shipping containers	1.5 (C)	10 mils	670 nm +/-10
ITF-14 < 25 mil X-dimension	GTIN-14	1.5 (C)	10 mils	670 nm +/-10
ITF-14 ≥ 25 mil X-dimension	GTIN-14	0.5 (D)	20 mils	670 nm +/-10
GS1 DataBar	GTIN-14, Other Application Identifiers (AIs)	1.5 (C)	6 mils	670 nm +/-10

Nine parameters are evaluated in the verification of linear bar codes. Five of the parameters are pass / fail parameters. This means a “Pass” is given an “A” grade or 4.0 and a “Fail” is given an “F” grade or 0.0. This is done when there is no middle ground for the parameter. For instance, the Quiet Zone has specifically prescribed attributes. If any of those attributes less than matches the specification, it is not a Quiet Zone. Either the bar code has a Quiet Zone or not. There is not a degree of Quiet Zone.

The pass / fail parameters include:

- Edge determination
- Reflectance minimum
- Edge contrast minimum
- Decode
- Quiet Zone

The graded parameters include:

- Symbol Contrast
- Modulation
- Defects
- Decodability

Each ISO parameter is explained in detail below.

7.2.1 Edge Determination

The evaluation of a bar code symbol starts with edge determination. This measures the number of lines in the Scan Reflectance Profile (SRP) that cross the global threshold, and makes sure that the number of “crossings” matches a valid symbology (type of bar code).

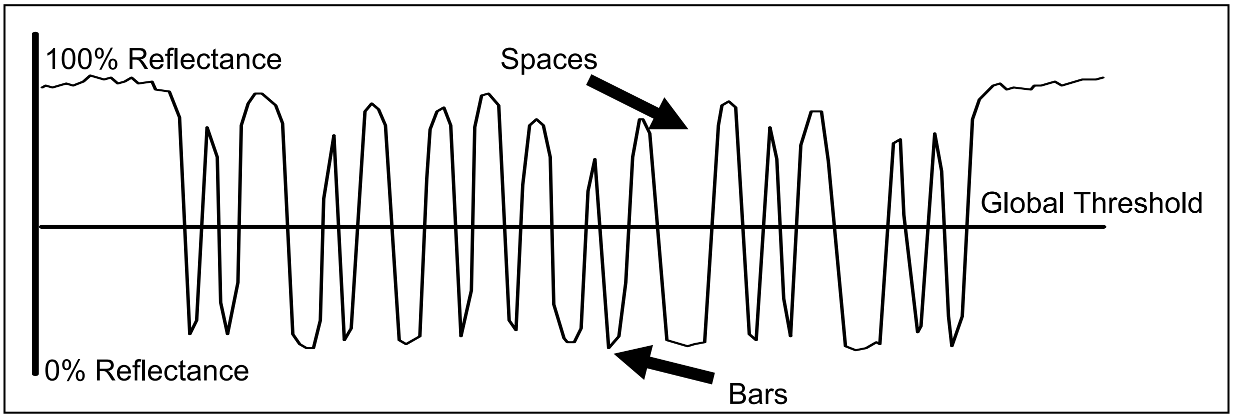

Figure 7.1 – Bar code represented in a Scan Reflectance Profile

7.2.2 Reflectance Minimum - (Rmin)

The lowest value shown on the SRP for at least one bar must be half or less than half the value from the highest reflectance value shown on the SRP for a space, referred to as $R_{max.}$ This is because, for a given level of Symbol Contrast, many scanners have greater difficulty distinguishing relatively light bars against a high-reflectance background than they do distinguishing darker bars against a relatively low reflectance background. The following figure shows a symbol printed in light brown on a white background, which appears to give good visual contrast. However, the symbol yielded an SRP that failed on this criterion. The R_{max} was 83%, so R_{min} should have been 41.5% or less. However; the actual R_{min} was 43%.

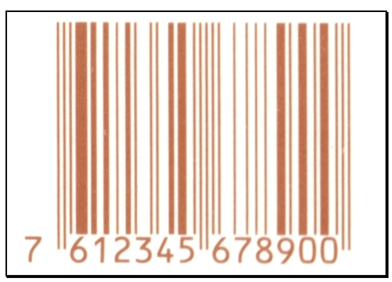

Figure 7.2 – Symbol with a failing minimum reflectance

7.2.3 Edge Contrast Minimum (ECmin)

Each transition from a bar to a space, or space to a bar, is an edge. Edge contrast is defined as the difference between peak values in that bar and space. Each edge in the SRP is measured, and the edge that has the minimum contrast in the transition from space to bar or bar to space is the edge contrast minimum.

Quiet Zones are considered spaces for this purpose. If EC_{min} is less than 15%, it is graded 0.0. Variations in ink weight in different parts of a symbol, or fluctuations in the background reflectance (such as with corrugated brown kraft substrates) are one cause of edge contrast problems. Another cause is that scanners tend to see narrow elements less distinctly than they do wider ones (a narrow space has lower apparent reflectance than a wide one, and a narrow bar appears similarly lighter than a wide one).

7.2.4 Decode

The next step is to apply the reference decode algorithm, the set of rules or steps for decoding a symbol defined in the symbology specification, to the elements "seen" in the Scan Reflectence Profile (SRP). If a valid decode results, the decode parameter passes and is given a grade 4.0. Otherwise, it fails (grade 0.0). If the wrong number of elements is seen, the decode fails.

NOTE: In American National Standards Institute (ANSI) standards, this last case is graded separately as an edge determination failure, although the final effect on the profile grade is the same.

A failure to decode may be evidence that the symbol is incorrectly encoded, which may include an incorrect Check Digit. Or it may indicate that the bars and spaces initially identified by the global threshold are too many or too few for a valid symbol, or that one or more edge position is ambiguous.

The ISO standard "decode" failure due to an incorrect number of elements present can be caused by the profile of one or more elements failing to cross the global threshold, or by a gross defect caused by one element being seen as three or more. This ISO decode failure corresponds to the separately graded "edge determination" failure in the ANSI standard. Verifiers following the ANSI methodology may report this error.

The following figure shows a symbol in which the narrow spaces have been partly filled in. This reduces their contrast below the global threshold and causes an edge determination, or decode, failure. This could also be interpreted as an extreme example of modulation.

Figure 7.3 – Symbol with "edge determination" problem

7.2.5 Quiet Zone

This measures whether a sufficient unprinted area exists per the symbology specification. Quiet Zones are a frequent source of scanning problems. Although the ISO standard does not directly require measurement of the Quiet Zones, it requires "any additional requirements specified by the application specification" be graded on a pass/fail basis. The *GS1 General Specifications* detail Quiet Zone requirements for all symbols used in the GS1 System. A Quiet Zone less than the minimum width will cause the profile grade to fail.

7.2.6 Symbol Contrast

Symbol Contrast is governed by the reflectance of the substrate and ink. A symbol printed in black ink on a white paper will almost certainly be a grade 4.0 symbol for Symbol Contrast because white papers typically have reflectance in excess of 75% and black ink will usually be around 3-8% reflectance. Colored backgrounds or colored inks will affect the result. Highly glossy materials may also appear to have a lower background reflectance than expected. The worst case may be when printing on a corrugated kraft material. This material may have a reflectance in a range between 27% and 40%, so even with a very dense, low reflectance ink, it can never achieve better than grade 1.0 for Symbol Contrast. Grade 1.0 includes Symbol Contrast values from 39% to 20%.

7.2.7 Modulation

Modulation, calculated as the percentage of Symbol Contrast represented by the minimum edge contrast, is reduced for the same reasons as minimum edge contrast is low in the symbol. A scanner tends to see spaces as narrower than bars, and also sees narrow elements as less distinct than wider ones. Consequently, if there is significant bar width loss, modulation is reduced. Measuring with an aperture that is too large for the X-dimension also reduces modulation.

7.2.8 Defects

Defects (called element reflectance non-uniformity or ERN), which show as irregularities in the SRP, may be caused by specks of extraneous ink in Quiet Zones or spaces, or by voids in the bars. In symbols printed on recycled or some other materials, local variations in reflectance of the background also show as defects. The significance of a defect is directly related to the depth of the irregularity it causes in the SRP.

The use of a smaller or larger measuring aperture than specified for the symbol in question will produce misleading defect grades. This is perhaps the strongest argument for ensuring that the right aperture size is used. Too small an aperture exaggerates the apparent size of a defect; too large an aperture tends to smooth it out.

Figure 7.4 – Symbol with defect failure from spots and voids

7.2.9 Decodability

This parameter tests for consistency in element widths throughout the bar code and compares the readability against the reference decode algorithm. Decodability measures the amount of “safe” margin left for the reading process after any errors in the printing of the bar code. The higher the percentage, the higher the grade and the larger the margin for the scanning system.

7.3 Troubleshooting Problems Uncovered by Verification

7.3.1 Defects

Defects are either light areas in bars or dark areas in spaces. Defects can be caused by bad ink transfer or rough print materials. Depending on the printing process, different actions can be taken:

- Flexography: Increase plate pressure (take care not to increase pressure to the point of distorting bar code images)
- Thermal direct / transfer: Other labels, higher temperature, other ribbon, higher pressure, lower printing speed

When grading a bar code, the aperture of the bar code verifier is important with regard to defects. Defects appear larger with too small an aperture and smaller with too large an aperture.

Possible causes of defects and the possible remedies include:

- Defective print head elements (thermal printing or ink jet printing) which tend to produce an unprinted line running through the symbol in the direction of printing.

  Solution: Clean or replace print head.

- Satellite ink droplets (ink jet printing).

  Solution: Clean head, change ink formulation.

- Haloing (flexography).

  Solution: Adjust impression pressure and / or ink viscosity.

- Incorrect matching of thermal transfer ribbons and substrate (poor adhesion of ink to surface).

  Solution: Use correct ribbon for substrate, use smoother substrate.

- Measuring aperture too small.

  Solution: Use verifier with correct aperture.

GS1 Symbology	Verifier Aperture
EAN/UPC	6 mils
ITF-14 @ ≥25 mils	20 mils
ITF-14 < 25 mils	10 mils
GS1-128 Extended Coupon Codes	6 mils
All other GS1-128	10 mils

7.3.2 Decode

This parameter controls Quiet Zones, Check Digits, and element determination. Sometimes, the code length will be checked. Errors are caused by design in preprint phase. Pay attention to the Quiet Zones. Quiet Zone definitions are minimum sizes with no tolerances. This requires preprint to add the print and positioning tolerances to the Quiet Zone minimum size.

If bar codes cannot be decoded, then the contrast deviation may be far out of specification. Another possibility is an invalid code caused by missing dots or errors in preprint. Check the color combinations (including background influences). Finally, check to determine if there are too many defects. A code table to check where something is missing can be a useful tool.

Possible causes of decode failure and the possible remedies include:

- Symbol incorrectly encoded.

  Solutions: Re-originate symbol; over-label with correctly encoded symbol.

- Check Digit incorrectly calculated.

  Solutions: Correct software error in origination system; re-originate symbol; over-label with correctly calculated symbol.

- Gross element width errors due to excessive print gain or loss, or defects.

  Solutions: Apply correct bar width adjustment when originating symbol; adjust press or printer settings.

- Too many elements detected due to defects.

  Solutions: Correct cause of defects; adjust press (relief printing processes) to reduce haloing; replace print head (thermal / ink-jet printing) too few elements detected (failure to cross global threshold).

7.3.3 Quiet Zone

Possible causes of Quiet Zone failure and the possible remedies include:

- Printed box surrounding symbol or other interfering print.

  Solution: Enlarge box; ensure symbol registration to other print allows adequate margins; use light margin indicators if possible.

- Symbol too close to label edge.

  Solution: Adjust label feed; reposition symbol farther from edge; use larger label size or smaller symbol.

7.3.4 Symbol Contrast

Possible causes of low Symbol Contrast and the possible remedies include:

- Background too dark.

  Solutions: Use lighter or less glossy material or change background color (if printed) to one with higher reflectance.

- Show through of contents.

  Solutions: Use more opaque material for package, or print opaque white underlay prior to printing symbol.

- Bars too light.

  Solutions: Change bar color to one with lower reflectance, increase ink weight or print head temperature (thermal printing). Note: Watch for consequential increase in bar widths.

7.3.5 Modulation

Possible causes of a low value of modulation and the possible remedies include:

- Local variations in background reflectance, such as fragments of darker material in a recycled material.

  Solution: Use a more consistent substrate or one with higher reflectance.

- Local variations in inking of the bars.

  Solution: Adjust press settings to ensure even or darker inking.

- Show through of contents.

  Solutions: Use more opaque material for package, or print opaque white underlay prior to printing symbol.

- Element(s) adjoining the edge in question appear excessively narrow relative to the measuring aperture used.

Solutions: Increase X-dimension; ensure correct measuring aperture is used; apply correct bar width adjustment when originating symbol; print bars marginally narrower than spaces of same modular dimension.

7.4 Available GS1 US Quality Tools

7.4.1 Calibrated Conformance Standard Test Cards

GS1 US provides calibrated test cards for each of the GS1 linear symbologies (EAN/UPC, ITF-14, GS1-128, and GS1 DataBar), which is produced and measured to a high degree of accuracy. This enables users to check that the readings obtained on their equipment are consistent and accurate. It contains both "perfect" symbols and symbols with engineered less-than-perfect characteristics (defects, low decodability, and low Symbol Contrast).

This card can also be used as a training tool for the operator of the verifier.

When using a *Calibrated Conformance Standard Test Card*, make sure you are using the correct aperture. It is listed on the card.

Use of the *Calibrated Conformance Standard Test Card* helps to end disagreements over bar code quality. Two trading partners (supplier and customer) may both verify symbols as a normal part of their process, yet they get different grade results. If only one of them checks the calibration of his verifier by using the test cards, only the one using the test card can be sure of his verifier's results. When both trading partners are using the *Calibrated Conformance Standard Test Card*, they are on the same page when it comes to bar code quality.

Figure 7.5 – GS1 US *Calibrated Conformance Standard Test Card*

7.4.2 Symbol Layout Templates

These are clear templates that are used to overlay GS1 linear symbols (EAN/UPC, ITF-14, GS1-128, and GS1 DataBar) to determine their magnification and if they have been truncated.

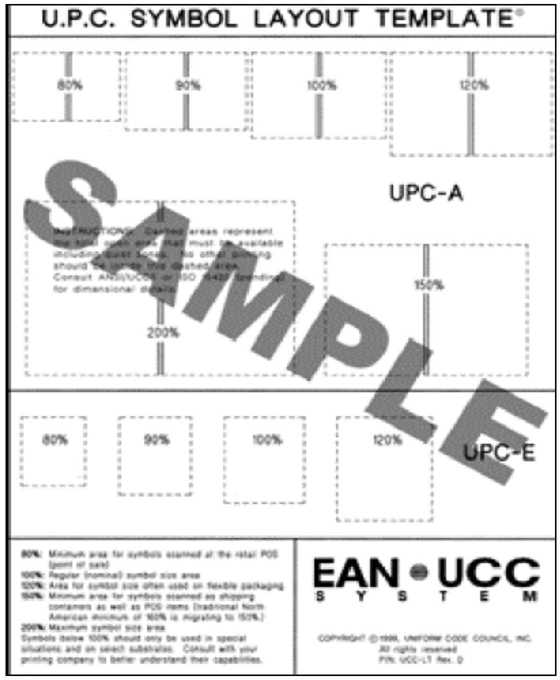

Figure 7.6 – *GS1 US Symbol Templates*

7.4.3 Symbol Size Gauges

This gauge enables you to determine the approximate magnification (width and height) for EAN/UPC symbols and X-dimensions for ITF, GS1-128, and GS1 DataBar symbols.

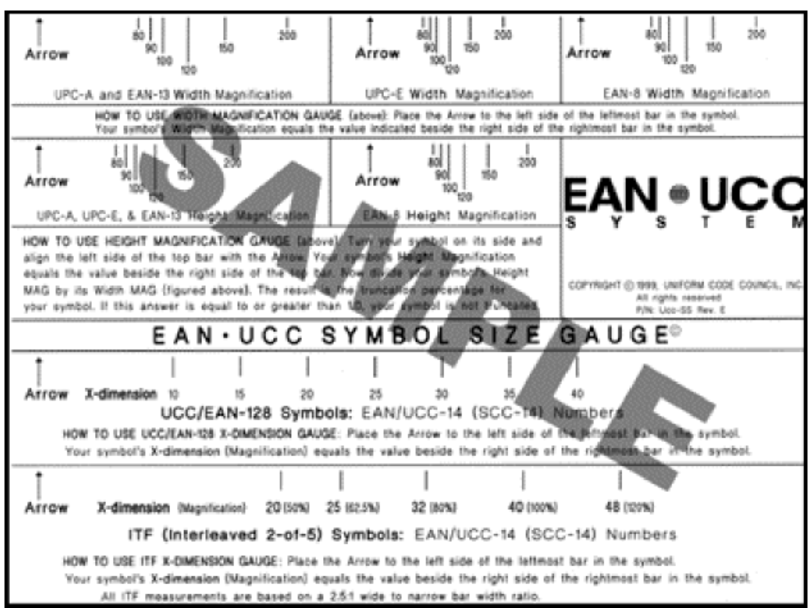

Figure 7.7 – *GS1 US Symbol Size Gauge*

7.4.4 Symbol Contrast Gauges

This gauge enables a designer to visually match an overlay to a proposed background color and then determine if the color used for the bars will have the minimum contrast necessary (for opaque package substrates only).

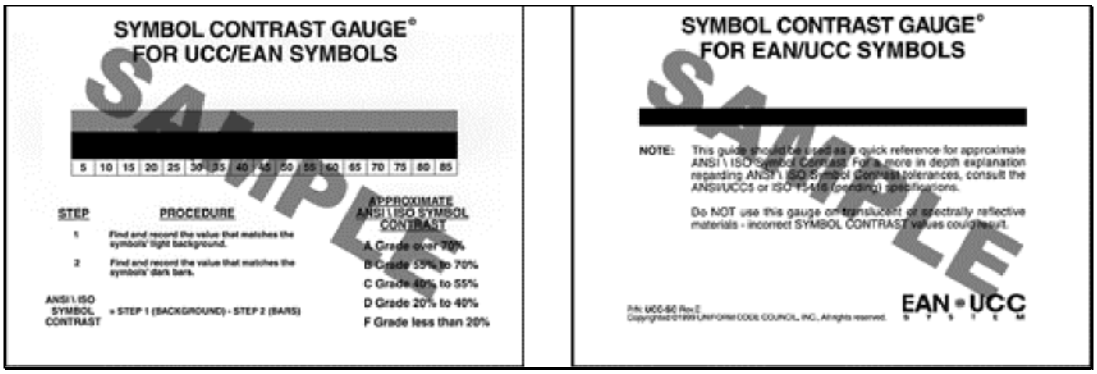

Figure 7.8 – *GS1 US Symbol Contrast Gauge*

Appendix A: Selecting a Verifier

GS1 Member Organizations are often asked for advice on the selection of equipment. Whereas they are expected to be commercially impartial, they ought to be in a position to advise inquirers on what to look for, and it may be helpful for them to encourage the inquirers to consider the following:

1. Will the primary use of the verifier be for monitoring production?

   If it will be used in the press-room by the machine operator, a simpler verifier able to give indications of bar width gain or loss may be sufficient - either by means of light-emitting diodes (LEDs) which show in broad steps how much gain or loss is occurring and in which direction, or by displaying the data in numerical form. A printout of the data may or may not be required. If it is to be used by quality control personnel, a more detailed analysis of both quality grades and traditional bar width gain/loss measurements will be required, and the unit should almost certainly incorporate either a printer or means of downloading data for record-keeping and trend analysis. In the special case of film master verification, both the construction of the device and its measurement accuracy are of equal importance.

2. Will the primary use of the verifier be to check that the finished symbol meets customer requirements?

   This may be in the manufacturer's premises, on the packaging line or in the warehouse; it may be at an intermediate distribution point; or it may be in the customer's receiving operation. In all these, the primary need is for a report of overall symbol grade, to check that it meets the basic grade requirement. In addition reporting of parameter grades is useful. The ability to provide a permanent record of results is highly desirable, both as evidence of compliance and in order to assist subsequent analysis of symbol characteristics.

   Whatever the purpose for which the verifier is required, there is a number of features to check which will help to determine the suitability of manufacturers' products for the particular need. Note that there will almost certainly be a relationship between the features supported and the price of the instrument, so if budgets are restricted, over-specification of the instrument should be avoided - although, equally, under-specification for the user's needs will only lead to frustrations in the future.

3. Does it apply the ISO methodology?

   Some will measure according to American National Standards Institute (ANSI) traditional method and others will measure according to the ISO Scan Reflectance Profile method. The ISO method requires 10 scans to be made and an average grade calculated. The *GS1 General Specifications* require the use of the ISO method for verification.

4. What parameters does it measure and report?

   The ISO method for verification requires testing a bar code on several parameters to ensure an adequate overall testing of the bar code’s quality, however, some verifiers may not *report* on all of these parameters. Some verifiers may only indicate whether a bar code passes or fails against these parameters and others will give detailed reports regarding the grade given for each parameter. The reporting method is important depending on how you will be using the information.

5. Has it been tested for conformance with *ISO/IEC 15426-1*?

   ISO/IEC 15426-1 is something of a companion document to the ISO specification on bar code print quality, and describes the use of a verifier to test a bar code against the parameters in ISO/IEC 15416. You will want to make sure that any verifier that you consider complies with these ISO specifications.

6. What is the optical arrangement (wand, mouse, laser, motorized head …)?

   You should first determine the environment in which you will be using a verifier. Do you want your verifier operator to physically move the reader across the bar code or do you wish the verifier to do this automatically? Do you require the verifier to be mobile or stationary? These questions play a roll in selecting the optical arrangement.

7. What wavelength light source does it use?

   The *GS1 General Specifications* require 670 nm ± 10 nm.

8. What measuring aperture(s) is / are available?

   Different apertures from the set (0.15 mm / 6 mil, 0.25 mm / 10 mil, 0.5 mm / 20 mil) are called for depending on the symbologies, X-dimensions, and applications.

9. What form of output is available (e.g. LEDs, display, printout of details and individual scan profiles, PC connection)?

   Verifiers have a variety of outputs: LED's only may simply indicate if a bar code passes or fails, You may get a full display of parameter grade but without print capabilities, The unit may have its own printer or accessory printer that can attach to the verifier, and other verifiers will give greatly expanded capability when connected to a PC utilizing the verifier's software.

10. Is it portable or does it require a fixed location?

    Whether portable or fixed, handling procedures must be established, and lighting and the ambient environment in the area of operation must be considered in conjunction with the manufacturers recommendations.

11. Is this verifier meant to go into, say, a production facility or must it remain in a quality lab?

    Many facilities will have separate verifiers for each environment, one to do spot checks on the production line, the other to troubleshoot quality problems. The same type of unit may not be appropriate for both places.

12. Can you accumulate data in the device and take it back to base to print it out?

    Having the ability to download data all at one time may be key to your operation rather than having to hand write and transcribe the data.

13. Does the verifier you are considering have the ability to store and archive data or bar code quality reports?

Being able to archive data and show a quality path may be important to a production facility, however an independent lab may not require that functionality.

14. Can it perform scan averaging (to meet the 10 scan requirement)?

    Some verifiers only work on the assumption of a single scan path and you must manually average 10 scan paths in order to comply with ISO methodology.

15. Does it provide traditional measurement of bar width gain 0 /loss?

    Some verifiers will report on quality based on both the traditional method and the ISO method.

16. What symbologies is it capable of verifying?

    You should ensure that your verifier supports all of the symbologies you use and at the Narrow bar widths you print them at.

17. Does it support GS1-128 specifically, or merely the generic Code 128?

    GS1-128 is a type of code-128 that uses FNC1 in the first position; your verifier should check for this in order to comply with the *GS1 General Specifications*.

18. Will different verifiers provide substantially different results when measuring the same symbol?

    All of your verifiers should operate consistently, and should be checked for calibration using the GS1 US *Calibrated Conformance Standard Test Cards*.

A precisely defined test program, the Verifier Conformance Testing Project, demonstrated that all instruments checked had the capability of consistent performance. Most instruments are capable of conforming to ISO/IEC 15426-1 requirements. No major difference in accuracy was noted between handheld and automatic scanning, but automatic scanning gave a somewhat narrower spread of results.

Appendix B: Getting Started

Becoming a Member

Manufacturers, suppliers, and those selling private label products with labels affixed to products must become members of GS1 US Partner Connections. This involves completing an application form and paying a membership fee. Membership fees depend on sales volume and estimated trade item (products and services) numbering requirements at the time of application. To obtain a membership form, contact the GS1 US customer support center or access the form via the GS1 US website at www.gs1us.org

GS1 Company Prefix

After receipt of the form and fee, GS1 US assigns each company a unique GS1 Company Prefix. The GS1 Company Prefix consists of a Company Number, which is allocated by GS1 US (or a GS1 Member Organization). Companies based outside the United States should visit GS1's website at www.gs1.org to determine the GS1 Member Organization for their country. Contact GS1 US at:

> GS1 US
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