BAR CODES
AND
THEIR APPLICATIONS

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MONOGRAPH SERIES
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NEW LIBERAL ARTS PROGRAM

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BAR CODES AND THEIR APPLICATIONS

Marian Visich, Jr.

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I. INTRODUCTION

For over 50 years, there have been many attempts to automate checkout counters in supermarkets. In the early 1930's, a group of students from the Harvard Business School proposed to use punch cards for this purpose. The basic idea was for shoppers to select punch cards for the products they were interested in purchasing from a catalog and hand them to the checkout person. The cards would be read by a punch card reader and the merchandise would be automatically delivered to the checkout counter on a conveyor belt from a storeroom. The punch card reader would also develop an itemized receipt for the customer and inventory records for the store management. The system was never developed because labor was very cheap and the supermarkets were not interested in the capital investment for the system.

In the late 1940's, a system based on a machine readable symbol on supermarket items was patented. The symbol consisted of a series of concentric circles of varying width which would be scanned by a light source.

The major breakthrough occurred in the 1970's when the National Association of Food Chains working with electronic equipment manufacturers developed the Universal Product Code (UPC) and the scanning equipment to decode the UPC symbol. It took almost a decade for product manufacturers to willingly print the UPC symbol on their products because of the initially limited number of supermarkets with scanning equipment.

Once the UPC proved to be a success in the grocery industry, bar codes were introduced in many other industries as a fast and accurate method of collecting information about products, documents or people. Today bar codes are used in manufacturing plants, on shipping cartons, in hospitals and libraries and on mail to automate the United States Postal System.

Studies have been conducted comparing the frequency of errors for data entry into a computing system by keyboard, using optical character recognition (OCR) equipment and by scanning bar codes. Various studies have concluded that on average there is one keyboard error for every 300 characters entered. Tests of OCR equipment show that on average there is one character substitution error out of 10,000 characters scanned. Since the Department of Defense requires its contractors to label all items it receives with a Code 39 bar code, it conducted a series of tests to determine the substitution error when scanning bar codes as part of its Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) Project. It found that for Code 39 bar code symbols of commercial quality, there was only one substitution error for 3,400,000 characters scanned. In addition to an error rate that is less than one ten-thousandth of keyboard entry, bar code scanning is more than four times faster for data entry than by keyboard.

When bar codes were being introduced in the 1970's, over 50 different bar codes were developed to satisfy the requirements of various industries. In this monograph, the six most popular bar code symbologies will be presented. These include the Universal Product Code and the European Article Numbering

Code which are used in supermarkets and other retail stores; the Interleaved Two of Five Code which is used on shipping cartons and for warehousing; the Three of Nine Code (Code 39) which is the only code that represents both digits and letters; Codabar which is used by libraries and preprinted air bills; and the POSTNET Code which is used by the United States Postal System. Following this, bar code scanning systems are described. In the final section, various bar code applications are presented. Automation of supermarkets and the United States Postal System are described in detail followed by a discussion of a wide range of other applications -- from manufacturing to the feeding of cows.

II. BAR CODE SYMBOLOGIES

A. Universal Product Code

In 1970, a grocery industry committee was formed to develop a standard code that could be used to identify retail items. The objective was to develop a symbol that could be read in either direction by an optical scanner to automate check out transactions and inventory control. The effort concluded with the selection of the Universal Product Code (UPC) Symbol as the industry standard in April 1973. At the present time, over 90% of the items sold in supermarkets have UPC symbols printed on them. Toy stores, liquor stores, drug stores and other retail stores have introduced UPC bar codes on items sold for rapid check-out and inventory.

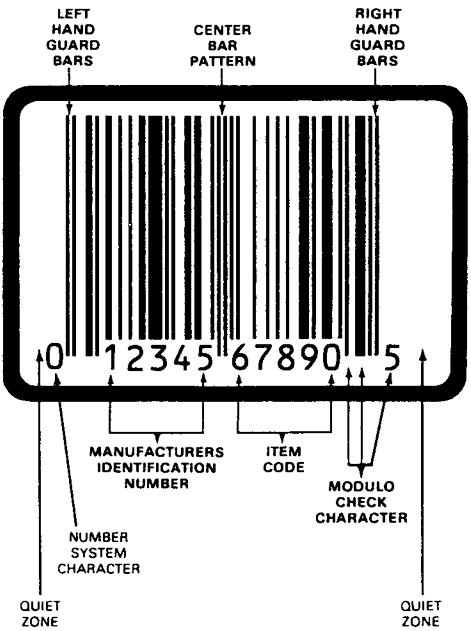


Fig. 1 General characteristics of the Universal Product Code Version A symbol. Reproduced with permission of Matthews International Corporation.

Figure 1 shows the general characteristics of the UPC Version A symbol that is printed on the vast majority of items sold as a means to achieve rapid check-out and inventory control. The symbol represents a 12 digit, all numeric code consisting of a number system character, a five digit manufacturer's identification number, a five digit item code number and a check digit. The digits represented by the UPC are printed across the bottom of the symbol in human readable form. For the symbols developed prior to 1985, the number system character digit was printed adjacent to the center of the left hand guard bars. The check digit was not required to be printed on the symbol, but if it was, it was located adjacent to the center of the right hand guide bars.

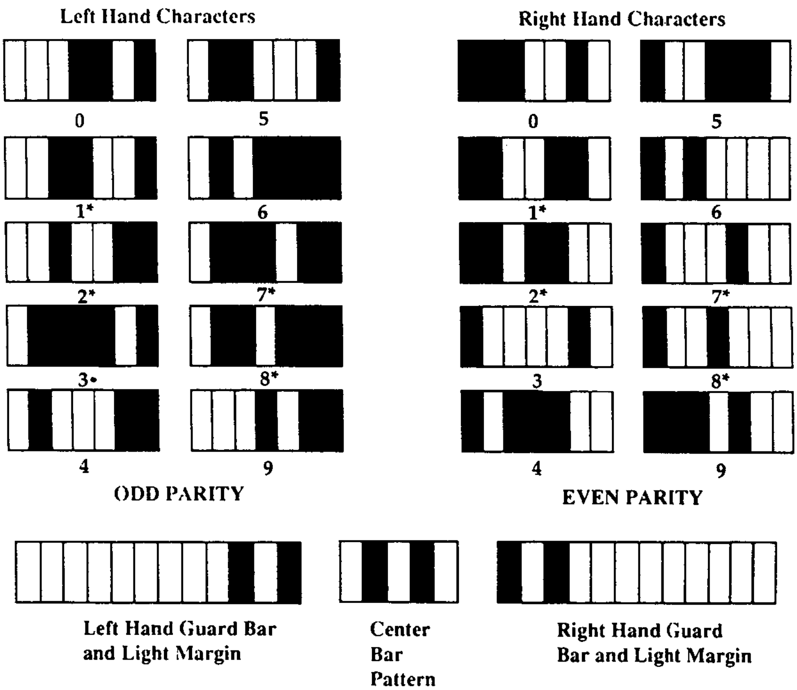


Fig. 2 UPC (Version A) character representation. Figure from *A Guide to Bar Coding.* Copyright © 1988 by Bar Code Systems, Inc. Reproduced with permission.

Each digit of the Uniform Product Code (Version A) is represented by a character consisting of two dark bars and two light spaces of different widths which occupy a total of seven data modules (Figure 2). The bars and spaces can be either one, two, three or four modules wide.

The total number of combinations of dark and light modules for seven data modules is 128. This can be reduced to a unique set of 10 characters representing the first six digits on the left side of the center bar pattern in the following manner:

- The first module is always light and the last module is always dark. This reduces the number of possible combinations to 32.
- Each symbol has only two bars and two spaces. This reduces the number of possible combinations to 20.
- The symbol contains an odd number of dark modules (odd parity). This reduces the number of possible combinations to 10.

For the characters representing the digits to the right of the center bar pattern, the dark modules are changed to light and the light modules changed to dark for the character representing the digit located to the left of the center bar pattern. Thus each character starts with a dark module and finishes with a light module. The number of dark modules is either two or four (even parity). For example, if the light modules are associated with the binary number 0 and the dark modules with the binary number 1, a 7 appearing in the manufacturer's identification number is represented by 0111011 (light - dark - dark - dark - light - dark - dark) while a 7 as a check digit is represented by 1000100 (dark - light - light - light - dark - light - light).

UPC Version A symbols can be read in either direction by a scanner. By requiring an odd number of dark modules in characters representing the first six digits, and an even number of dark modules for the last six digits, the scanner can determine the direction that the UPC symbol is being scanned. In all other bar codes the direction of scan is determined by using different start and stop guard bar patterns. The center bar pattern divides the UPC Version A symbol into even and odd parity representations of the digits. Twin beam slot scanners used in supermarket check out counters are designed such that at least one beam will scan each half of the symbol as it is passed over the scanner.

The first digit of the UPC Version A symbol is the number system character which describes the type or category of products. The number system character assigned to various products are as follows:

0 all nationally branded items except the following

2 random weight items such as meat, cheese and produce which are packaged at the store level

3 National Drug Code and National Health Related Items Code in 10 digit code length

4 in-store marking of non-food items

5 refund coupons

6, 7 assigned to items from industrial manufacturers, wholesaler-distributors and dealer/end users whose products are not typically scanned at retail point-of-sale (examples: screws, wire, pipe fittings, etc.)

1, 8, 9 reserved for uses unidentified at the present time

The manufacturer's identification number is a five digit number assigned by the Uniform Code Council, Inc. The item code number is a five digit number assigned by the manufacturer. It is unique for each type of consumer package and/or shipping container. Products sold in multipacks are assigned an item number for the smallest consumer sale unit and a different item number for the multipack. For example, a box of 25 Twinings Irish Breakfast Tea Bags has a UPC symbol corresponding to 0-70177-05146-4 while the wrapper on an individual tea bag has the code 0-70177-05009-2. If a manufacturer produces more than 100000 items (item code numbers 00000-99999), the Uniform Code Council assigns a second manufacturer's identification number.

The final digit on the UPC symbol is a scanner readable check digit which enables the scanner to immediately verify the accuracy of the scanned 11 digit code. It is determined in the following way. Starting with the first digit of the code (number system character), sum all of the digits in the odd positions. Multiply the sum by three and add to the product the sum of all the digits in the even positions. The modulo-10 check digit is the smallest number which when added to the sum produces a multiple of 10.

If the UPC symbol cannot be scanned because of a defect, the checkout person manually enters the 12 digit code printed below the UPC symbol into the cash register. The most common error in manually entering data is the transposition of digits. By multiplying the sum of the odd digits by three, transposition errors can be discovered. Although the algorithm for determining the check digit multiplies the sum of the odd digits by three, the sum could have been multiplied by any non-zero digit except one for determining transposition errors.

Kellogg's
Common Sense

0 38000 12100 5

Fig. 3 UPC Version A symbol for Kellogg's Common Sense cereal

Figure 3 is the UPC symbol from a box of Kellogg's Common Sense cereal. The manufacturer's identification number for Kellogg is 38000. The item code number, 12100, designates a 16.8 ounce box of Common Sense Oat Bran-Flakes of natural oat bran. The check digit is determined in the following manner

$$3 \times (0 + 8 + 0 + 1 + 1 + 0) + (3 + 0 + 0 + 2 + 0) = 35$$

$$\text{Modulo-10 check digit} = 40\text{-}35 = 5$$

Except for refund coupons and random weight items, the price of the item is not included in the UPC symbol. Different supermarket chains may charge different prices for an item or the price may change during a sale. Since the manufacturer of the item determines the amount refunded and the group of items for which the refund is valid, this information must be included in the UPC symbol on refund coupons. Instead of a five digit item code number, the second five digit number is broken up into a three digit family code and a two digit value code.

Figure 4 is a refund coupon for Nabisco Oreo and Chip Ahoy cookies. The family code 100 indicates that the coupon is valid for the purchase of one package of Oreo Chocolate Sandwich Cookies -- 14 oz. or larger -- and one package of Chips Ahoy Chocolate Cookies -- 12 oz. or larger.

Fig. 4 Refund Coupon for Oreo and Chips Ahoy Cookies

The Uniform Code Council is also responsible for setting the standards for the value code. Of the possible 100 values, 76 have been assigned and 24 have been reserved for future use. Some of the value codes are equal to the redemption value of the coupon (e.g., value code 39 corresponds to a coupon value of $0.39) while others are not (e.g., value code 61 corresponds to a coupon value of $10.00). Fourteen of the assigned value codes have been designated for use where two items with the same family code must be purchased to redeem the coupon. For example, the value code 33 on the Nabisco coupon corresponds to "Buy 2, get $1.00 off."

In applications where space is a premium, a zero-suppression symbol (UPC Version E symbol) has been developed by the Uniform Code Council. The Version E symbol is a six character symbol which provides information about the manufacturer and the item. Neither the number system character or the modulo check character is encoded in the zero-suppression symbol.

As specified in the *UPC Symbol Specification Manual - January 1986* of the Uniform Code Council, the six characters are derived in the following way:

- If the last three digits of the five digit manufacturer's identification number are either 000, 100, or 200; 1000 different item numbers can be encoded in the Version E symbol. The six character symbol consists of the first two digits of the manufacturer's identification number, followed by three digits representing the item number, followed by the third digit of the manufacturer's identification number (i.e. 0, 1, or 2).

- If the last three digits of the five digit manufacturer's identification number are either 300, 400, 500, 600, 700, 800, or 900; 100 different item numbers can be encoded in the Version E symbol. The six character symbol consists of the first three digits of the manufacturer's identification number, followed by two digits representing the item number, followed by the digit 3.

- If the manufacturer's identification number ends in 10, 20, 30, 40, 50, 60, 70, 80 or 90; 10 diffferent item numbers can be encoded in the Version E symbol. The six character symbol consists of the first four digits of the manufacturer's identification number, followed by one digit to represent the item number, followed by the digit 4.

- If a manufacturer's identification number does not end in zero, only five different item numbers can be encoded in the Version E symbol. The six character symbol consists of the complete five digit manufacturer's identification number followed by the digit 5, 6, 7, 8 or 9 which represents the item number.

As in Version A, each digit is represented by a character consisting of two dark bars and two light spaces of different widths which occupy a total of seven data modules. In Version E, however, all characters start with a light module and end with a dark module. Each digit is represented by both an odd parity (odd number of dark modules) character and an even parity (even number of dark modules) character as shown in Figure 5 in binary representation. The odd parity characters representing the digits are the same as in Version A.

Character Value	Odd Parity	Even Parity
0	0001101	0100111
1	0011001	0110011
2	0010011	0011011
3	0111101	0100001
4	0100011	0011101
5	0110001	0111001
6	0101111	0000101
7	0111011	0010001
8	0110111	0001001
9	0001011	0010111

Fig. 5 UPC (Version E) character representation in binary notation

Each UPC Version E symbol contains three digits represented by odd parity characters and three represented by even parity characters. The parity sequence of characters is determined from the value of the modulo check character of the corresponding UPC Version A symbol. The zero-suppression parity pattern is shown in Figure 6.

Modulo Check Character Value	Character Location Number 1	2	3	4	5	6
0	E	E	E	O	O	O
1	E	E	O	E	O	O
2	E	E	O	O	E	O
3	E	E	O	O	O	E
4	E	O	E	E	O	O
5	E	O	O	E	E	O
6	E	O	O	O	E	E
7	E	O	E	O	E	O
8	E	O	E	O	O	E
9	E	O	O	E	O	E

Fig. 6 UPC Version E symbol parity pattern

An example here might be helpful. The Universal Product Code (Version A) of a 12 pack carton of 12 fluid ounce cans of Pepsi is represented by:

0-12000-00016-4

Since the last three digits of the manufacturer's identification number are 000, and the item code number is 016, then the Universal Product Code (Version E) is represented by

120160

and is shown in Figure 7. The digits represented by the UPC Version E symbol are printed across the bottom of the symbol in human readable form. In addition, the number system character and the modulo check character from the corresponding Version A symbol are also printed at the bottom of the symbol ahead of the left hand guard bars and after the right hand guard bars, respectively. According to Figure 6, the parity sequence based on a modulo check character of 4 is even-odd-even-even-odd-odd.

Fig. 7 UPC Version E symbol for a 12 pack carton of Pepsi cans

B. European Article Numbering

In 1977, 12 European countries (Austria, Belgium, Denmark, Finland, France, West Germany, Italy, Netherlands, Norway, Sweden and Switzerland) signed the European Article Numbering (EAN) Memorandum of Agreement forming the EAN Association. The initial objective of EAN was to provide a unique and unambiguous article numbering system to facilitate check out operations in grocery stores. In 1981 the name of the governing organizations was changed to the International Article Numbering Association EAN to reflect the international membership of the organization. According to the *EAN Annual Report 1988*, membership has grown to 42 countries from five continents. Although the United States and Canada are not members of EAN, there is close cooperation between EAN and UCC (representing the United States and Canada) to insure that the UPC and EAN codes are compatible. The agency in an EAN country which has the legal status to represent the manufacturers and distributors of that country is known as the EAN Numbering Organization.

Over 105,000 company members (distributors, manufacturers and retailers) participate in the EAN system. Japanese companies account for over 35% of the company members. There are 78,000 scanning stores located in EAN countries. More than three-quarters of the scanning stores are located in Japan with Seven-Eleven stores being the largest retailer using scanners (3,500). France has the second largest number of scanning stores (3,470). Czechoslovakia, Hungary, and Russia are members of EAN. They have 1, 10, and 2 scanning stores, respectively. It is estimated that there are 25,000 scanning stores and 75,000 company members in the UPC system in Canada and the United States.

The EAN symbol represents a 13 digit, all numeric code consisting of a three digit country code which identifies the EAN Numbering Organization representing it, a nine digit item identification number and a check digit. The digits represented by the EAN symbol are printed across the bottom of the symbol in human readable form.

The format of the EAN symbol is similar to the format of the UPC Version A symbol. However, the characters used to represent the digits to the left of the center bar pattern are the UPC Version E characters shown in Figure 5 in binary notation. The characters to the right of the center bar pattern are the UPC Version A even parity characters.

7 616100 000449

Fig. 8 EAN symbol for a 100 gram bar of Cailler's Almond Chocolate

Figure 8 shows the EAN symbol for a 100 gram Cailler almond chocolate bar produced in Switzerland. As in the UPC Version A symbol, six digits are represented between the left hand guard bars and the center bar pattern (last two numbers of the country code [61] and the first four digits of the item identification number [6100]) and six digits between the center bar pattern and the right hand guard bar (last five digits of the item identification number [00044] and the check digit [9]). The first digit of the country code [7] is not encoded in the symbol by a character, but is represented by the parity pattern of the six characters between the left hand guide bar and the center bar pattern as shown in Figure 9.

First Digit of Country Code	Parity Pattern
0	OOOOOO
1	OOEOEE
2	OOEEOE
3	OOEEEO
4	OEOOEE
5	OEEOOE
6	OEEEOO
7	OEOEOE
8	OEOEEO
9	OEEOEO

Fig. 9 EAN symbol parity pattern

The country code is assigned by the International Article Numbering Association EAN located in Brussels, Belgium. Prior to 1981, EAN member countries were assigned a two digit country code. At the present time countries allocated a two digit country code may simply regard it as ten three digit codes. For example, Denmark was originally assigned 57 as its country code. It can now use the numbers 570 to 579 as its country code on its EAN symbols. Tabulated below are representative country codes assigned by EAN:

Code	Numbering Organization and Country
00 to 09	UCC (USA and Canada)
30 to 37	GENCOD (France)
460 to 469	USSR CCI (USSR)
49	Distribution Code Center (Japan)
779	CODIGO (Argentina)
860	JANA (Yugoslavia)
959	PNGPNA (Papua New Guinea)
977	Periodicals (ISSN)
978 to 979	Books (ISBN)
98 to 99	Coupon numbers

The nine digit item identification number is the responsibility of the EAN Numbering Organization in a particular country. It is recommended by the International Numbering Association EAN that the first four digits represent the manufacturer's identification number and the following five digits represent the article number.

The final digit on the EAN symbol is a check digit to immediately verify the accuracy of the scanned 12 digit code. It is determined in the following way. Starting with the second digit (second digit of the country code), sum up all of the digits in the even positions. Multiply the sum by three and add to the product the sum of all of the digits in the odd positions. The modulo-10 check digit is the smallest number which when added to the sum produces a multiple of 10. For example, the check digit for the EAN symbol shown in Figure 8 is determined in the following manner:

$$3 \times (6 + 6 + 0 + 0 + 0 + 4) + (7 + 1 + 1 + 0 + 0 + 4) = 61$$

$$\text{Modulo-10 check digit} = 70\text{-}61 = 9$$

The EAN Numbering Organization for the United States and Canada is the Uniform Code Council. They have been assigned the two digit country code numbers 00 to 09. In three digit format this is equivalent to 000 to 099. For consistency between the EAN symbols and the UPC symbols, the Uniform Code Council has assigned the second digit of the country code to correspond to the number system character of the UPC Version A symbol and the third digit of the country code to be the first digit of the manufacturer's identification number. As a result, the UPC symbol and the EAN symbol for a product manufactured in the United States or Canada are identical. For example, the only difference between the EAN symbol for the Kellogg's Common Sense (cereal) and the corresponding UPC Version A symbol shown in Figure 3 is that the human readable digits would be 0-038000-121005 for the ENA symbol and 0-38000-12100-5 for the UPC symbol. As a result, scanners designed to read ENA symbols *can* read the UPC symbols. However, scanners designed to read UPC symbols *cannot* read ENA symbols.

C. Interleaved Two of Five Code

The Uniform Product Code is a complex code in that it uses bars and spaces of several widths and the character representing a particular digit is different on either side of the center bar pattern of the UPC symbol. In the Interleaved Two of Five Code and the Code 39 bar codes, there are only two widths for bars and spaces. In binary notation, a narrow bar or space is represented by a 0 and a wide bar or space is represented by a 1.

If two similar objects are placed in any of five different locations, then there are ten possible combinations. The Two of Five Code developed in the late 1960's is an all numeric code based on this concept to represent the digits 0-9. Each of the digits in this code is represented by two wide bars and three narrow bars as indicated in Figure 10. The character pattern is derived by associating the digits 1, 2, 4, 7 and parity with the 5 positions in the code starting from the left. The sum of the digits corresponding to the location of the wide bars equals the value of the character except for zero where the sum is equal to 11. The parity position contains a wide bar for the digits 1, 2, 4, and 7 to ensure two wide bars in each of the characters.

Character Value	Code
0	00110
1	10001
2	01001
3	11000
4	00101
5	10100
6	01100
7	00011
8	10010
9	01010

Fig. 10 Two of Five Code character representation in binary form

The wide bar is conventionally three times the width of the narrow bar. The bars representing a digit are separated by narrow spaces equal in width to a narrow bar. As a result, all information regarding the number represented by the symbol is contained in the bars. The direction of scan is determined by using different start (110 in binary notation) and stop (101 in binary notation) characters. The major disadvantage of the Two of Five Code is that each data character is represented by a total of 14 modules. Since no information is contained in the spaces, this results in a relatively long symbol for a given number in comparison to other numeric symbologies.

To overcome the disadvantage inherent in the Two of Five Code, Dr. David Allais, Vice President of the INTERMEC Corporation, developed the Interleaved Two of Five (I 2/5) code in 1972. In the I 2/5 Code both the bars and spaces represent digits. The odd numbered digits are represented by the bars and the even number digits by spaces.

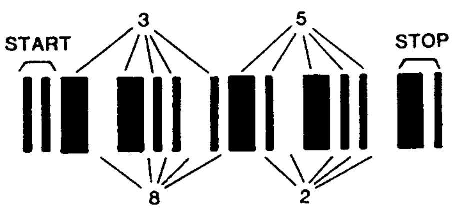


Fig. 11 Interleaved Two of Five symbol for the number 3852. Figure from *Bar Code Symbology* by David C. Allais. Copyright © 1984 INTERMEC Corporation. Reproduced with permission.

Figure 11 shows the Interleaved Two of Five symbol for the number 3852. The character representation of the digits by bars and spaces is the same as the Two of Five Code in binary representation. The start character is represented by four narrow modules starting with a bar. The stop character is represented by a wide bar followed by two narrow modules.

Since the I 2/5 symbol is based on the pairing of digits in bars and spaces, only a number with an even number of digits can be represented. If a number contains an odd number of digits, it must be preceded by a 0 to produce an even number of digits.

The accuracy of scanning the Interleaved Two of Five Code can be enhanced by using a check digit similar to the check digit of the Universal Product Code. When using a check digit, the number represented by the code must have an odd number of digits. If the number has an even number of digits, it must be preceded by a 0. The digits in the odd positions are summed and multiplied by three. The sum of the digits in the even positions is added to the product. The check digit is the smallest digit which when added to the weighted sum produces a multiple of 10. Consider the number 9246. Since the number contains an even number of digits, it must be preceded by a 0 to produce the number 09246. The check digit is calculated in the following manner:

$$3 \times (0 + 2 + 6) + (9 + 4) = 37$$

Modulo-10 check digit = 3

Therefore, the Interleaved Two of Five symbol would represent the number 092463.

To show the advantage of using the Interleaved Two of Five Code to represent a number in comparison to the Two of Five Code, consider the number of modules required to represent an eight digit number including start and stop characters using both codes. The ratio of wide to narrow elements will be assumed to be 3 and the thickness of a narrow element (module) 0.02 inches. The length of the Two of Five symbol would be 121 modules or 2.42 inches. The corresponding Interleaved Two of Five symbol would be 72 modules or 1.45 inches -- a savings of 40%.

D. Three of Nine Code (Code 39)

The Universal Product Code and the Interleaved Two of Five Code are numeric codes only. In December, 1974, Dr. David Allais of INTERMEC proposed the structure for Code 39 -- a fully alphanumeric code of variable length. The individual characters of the code were developed by Ray Stevens and a working specification for Code 39 were written in January, 1975.

According to Allais, the code was so named because there were only 39 characters in the original code. At the present time there are 44 characters in

Code 39. Each of the characters consists of nine elements (five bars and four intervening spaces) of which three are wide and six are narrow. Except for four special characters ($, /, +, and %), each of the characters consists of two wide bars out of five (ten possible combinations) and one wide space out of four (four possible combinations) for a total of 40 characters. The four special symbols consist of five narrow bars, three wide spaces, and one narrow space. The complete set of characters for Code 39 is shown in Figure 12.

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

Fig. 12 Code 39 character representation. Figure from *Bar Code Symbology* by David C. Allais. Copyright © 1984 INTERMEC Corporation. Reproduced with permission.

According to the code specifications published by the Automatic Identification Manufacturers, the ratio of widths of the wide to narrow elements in a character can range between 2.0 and 3.0. The ratio of widths of the intercharacter spaces to the narrow spaces used in a symbol can range from 1.0 to 5.3. For a given Code 39 symbol the above ratios are constant.

The start/stop character is the asterisk (Bars 00110, Spaces 1000) which can only be used as the first and last character of a Code 39 symbol. Since the start/stop character is not symmetric, it can be used to determine the direction of the scan. The message encoded in the Code 39 symbol is printed below the symbol in human readable form except for the asterisks which represent the start/stop symbols.

Code 39 has also been used to encode the entire ASCII character set (128 characters) used in computer software. This is achieved by using the characters $, /, % and + as precedent symbols with the 26 letters. To enter or leave the ASCII mode, the bar code scanner reads the following control labels which are encoded into the Code 39 bar code symbol:

* + $ *	Enter ASCII mode
* - $ *	Leave ASCII mode

Examples of the encoding of the ASCII character set with Code 39 are

	ASCII	Code 39
	a	+ A
	<	% G
	(	/ H
(carriage return)	CR	$ M

The self checking property of Code 39 makes it highly error resistant. The Department of Defense in 1981 conducted a study to determine the accuracy of reading Code 39 symbols. It found that there was only one substitution error in 3.4 million characters scanned. In situations where greater accuracy is required, a check character is included in the symbol.

Two schemes are used in determining the check character. In both schemes, each of the characters, except the asterisk, is assigned a numerical value from 0 to 42 as shown in Figure 13.

Character	Value	Character	Value	Character	Value
0	0	F	15	U	30
1	1	G	16	V	31
2	2	H	17	W	32
3	3	I	18	X	33
4	4	J	19	Y	34
5	5	K	20	Z	35
6	6	L	21	-	36
7	7	M	22	.	37
8	8	N	23	SPACE	38
9	9	O	24	$	39
A	10	P	25	/	40
B	11	Q	26	+	41
C	12	R	27	%	42
D	13	S	28		
E	14	T	29		

Fig. 13 Code 39 numerical assignment for computing the check character.

In the first scheme, the numerical values of all of the characters used in the symbol are summed. The sum is then divided by 43 and the remainder determined. The character whose numerical value is equal to the remainder is the check character which is added at the end of the message. Consider the message

J 7 0 C 1 6 F M

The sum of the numerical values of the characters is

$$19 + 7 + 0 + 12 + 1 + 6 + 15 + 22 = 82$$

Dividing the sum by 43 the quotient is 1 and the remainder 39. The character corresponding to the numerical value of 39 is $. Therefore the message encoded in the Code 39 symbol would be:

J 7 0 C 1 6 F M $

One of the drawbacks with this scheme is that if two characters are transposed during manual entry of a symbol that cannot be read by a scanner, the check character remains the same.

The second scheme overcomes this problem by weighting adjacent characters: starting with the last character in the message to be encoded, the weighting constant is 1. Moving to the left, the weighting constant of the second character is 2; the third character is 3, etc. The numerical value of each of the characters is multiplied by its corresponding weighting constant and the results summed. As in the first scheme, the sum is divided by 43 and the remainder determined. The character whose numerical value is equal to the remainder is the check character. Consider again the message:

	J	7	0	C	1	6	F	M
Numerical value	19	7	0	12	1	6	15	22
Weighting constant	8	7	6	5	4	3	2	1

Sum $152 + 49 + 0 + 60 + 4 + 18 + 30 + 22 = 335$

Dividing the sum by 43 the quotient is 7 and the remainder 34. The character corresponding to the numerical value of 34 is Y. Therefore the message to be encoded in the Code 39 symbol would be:

J 7 0 C 1 6 F M Y

E. Codabar

Codabar was developed in 1972 by the Monarch Marking Systems Division of Pitney Bowes for department store retail price labels. A version of

Codabar was considered by the grocery industry committee before it selected the Universal Product Code. At present, Codabar is mainly used in libraries and for labels on blood bags, preprinted air bills and photo finishing envelopes.

Each Codabar character consists of seven elements: four bars and three spaces. The 10 digits, the minus sign (-) and the dollar sign ($) each have one wide bar and one wide space (Code 2 of 7). Eight additional characters are represented with three wide elements (Code 3 of 7). The four start/stop characters (a, b, c, d) each have one wide bar and two wide spaces. Four special characters (:, /, ., +) each have three wide bars and no wide spaces. The complete set of characters for Codabar is shown in Figure 14 using the binary notation 0 to represent a narrow element and 1 to represent a wide element.

A Codabar symbol rarely includes a check digit. Studies conducted by the American Blood Commission's Committee for Commonality in Blood Banking Automation found a first pass read rate of 99 percent and a substitution error rate of better than one in one million characters. The four start/stop characters can be used at either end of the symbol. As a result there are 16 unique start/stop combinations to identify label type or other information.

Character	Bars	Spaces
0	0001	001
1	0010	001
2	0001	010
3	1000	100
4	0100	001
5	1000	001
6	0001	100
7	0010	100
8	0100	100
9	1000	010
-	0010	010
$	0100	010
a	0100	011
b	0001	110
c	0001	011
d	0010	011
:	1011	000
/	1101	000
.	1110	000
+	0111	000

Fig. 14 Codabar character representation in binary form.

F. United States Postal Service Code

To accelerate the sorting of mail using automated equipment, the United States Postal Service initiated the use of POSTNET (Postal Numeric Encoding Technique) in 1983. POSTNET is a bar code representation of ZIP Code information on letter mail which can be reliably read by relatively inexpensive bar code sorters.

POSTNET is an all numeric code with all of the characters represented by three short bars and two long bars. In binary notation, the short bars are represented by 0 and the long bars by 1. Figure 15 presents the POSTNET character representation in binary form. The character pattern is derived by associating the digits 7, 4, 2, 1, and 0 with the five positions in the code starting from the left. The sum of the digits corresponding to the location of the tall bars is equal to the value of the character except for zero where the sum is 11. The start/stop guard bar character is a long bar.

Character Value	Code
0	11000
1	00011
2	00101
3	00110
4	01001
5	01010
6	01100
7	10001
8	10010
9	10100

Fig. 15 POSTNET character representation in binary form.

Both five digit and nine digit ZIP Codes can be represented by POSTNET. A check digit is included in the bar code to increase the accuracy of scanning. The check digit is determined by first finding the sum of the individual digits of the ZIP code. The module-10 check digit is the smallest number which when added to the sum produces a multiple of 10. For example, the nine digit ZIP Code (ZIP + 4) for the Telescope Making magazine as shown on the pre-printed business reply postcard in Figure 16 is 53233-9968. The sum of the ZIP Code digits is 48; therefore the modulo-10 check digit that is included as the last character in POSTNET is 2.

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 3889 MILWAUKEE, WI

POSTAGE WILL BE PAID BY ADDRESSEE

TELESCOPE
MAKING
1027 North Seventh Street
Milwaukee, WI 53233-9968

Fig. 16 Telescope Making magazine business reply postcard

III. BAR CODE SCANNERS

The purpose of a bar code scanning system is to read the information stored in a bar code symbol so that the data can be entered directly into a control computer for further processing depending upon the application. In this section, the basic operation of optical scanners will be discussed first. Following this, a detailed description of the three types of scanners -- wand, fixed beam and moving beam -- will be presented.

A. How Optical Scanners Work

Figure 17 shows the basic operational characteristics of an optical scanning system used for separating packages on a warehouse conveyor belt. Although the figure is for a moving laser beam scanner, the basic operating principle is the same for both fixed beam and moving beam scanners.

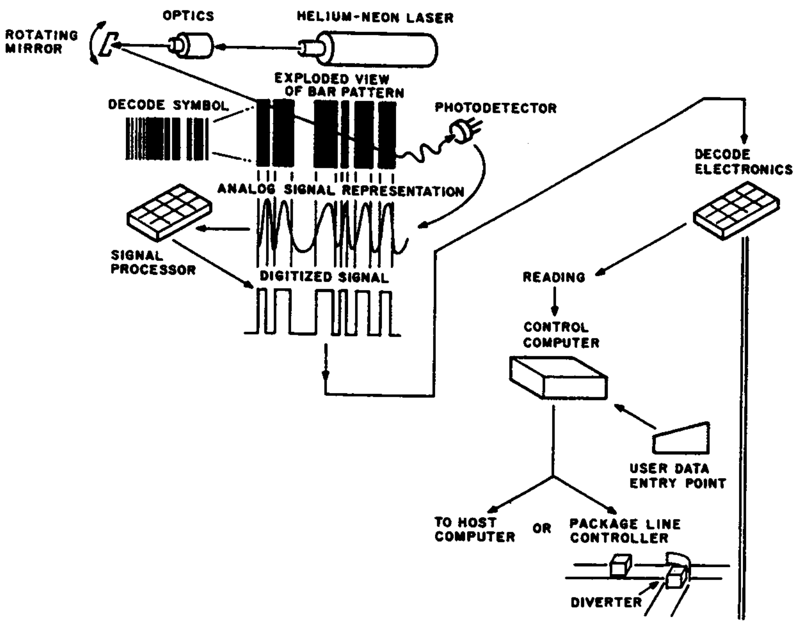


Fig. 17 Optical scanning system. Figure from *Reading Between the Lines* by Craig K. Harmon and Russ Adams. Copyright © 1984 Helmers Publishing, Inc. Reproduced with permission.

As shown in Figure 17, when a small diameter beam of light from the helium-neon laser moves across a bar code symbol, light is absorbed by the dark bars and reflected by the light spaces. The reflected light is picked up by a photodetector producing an analog voltage signal proportional to the intensity of the light striking it. A signal processor converts the analog signal from the photodetector to a digital signal. The digital signal assumes only one of two values corresponding to either the maximum or minimum amount of light picked up by the photodetector as opposed to the analog signal which varies over a continuous range of values.

Figure 18 shows the analog to digital conversion of a bar code symbol using a scanner. If the output voltage from the photodetector is above the decision threshold, the signal processor reads the pulse as a light space. For output voltages below the decision threshold, the signal processor reads the pulse as a dark bar. As a result, the digital pulse widths correspond to the scanned bars and spaces of the symbol. The output from the signal processor is then decoded into the appropriate bar code symbology and the data transmitted to a central computer.

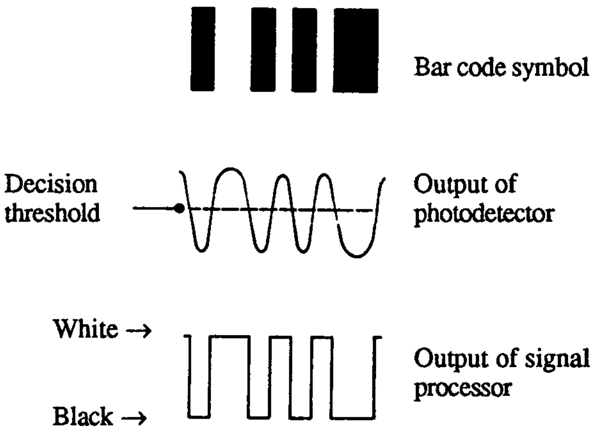


Fig. 18 Analog to digital conversion. Figure from *Bar Code Scanning Reference Guide.* Copyright © 1980 MSI Data Corporation. Reproduced with permission.

The diameter of the light spot from the scanner relative to the width of the narrowest space on the bar code symbol to be read is critical in the design of a scanner. In an optimum design, the spot diameter should be approximately equal to the width of the narrowest space. If the spot diameter is larger, the output from the photodetector will result in poor resolution of the symbol as shown in Figure 19. As can be seen in the figure, when the light spot is located in the center of a narrow space, only part of the light is reflected since a portion of the light falls upon the adjacent dark bars. The voltage output of the photodetector is much less than that corresponding to the case where the light spot is located in the center of a wide space. As a result, the output of the signal processor does not accurately represent the scanned bar code symbol. If the spot diameter is much smaller, it would respond accurately to the edges of the bars.

However, it would also respond to various printing errors such as ink spots and voids, resulting in poor resolution.

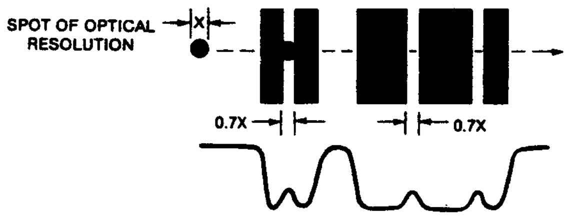


Fig. 19 Poor scanner beam resolution. *Scanning Products on the Move.* Copyright © 1983 Automatic Identification Manufacturers, Inc. Reproduced with permission.

The decoder receives the digital signal from the signal processor and interprets it to obtain the information stored in the bar code symbol. Consider the decoding of the bar code character shown in Figure 20. When the width of an electrical signal from the output of the signal processor is measured, it is measured in terms of time (milliseconds) not in terms of length (inches). For a given scan velocity, the output from the signal processor shows that the time to scan the four bars were t_1, t_3, t_5 and t_7, respectively; while the time to scan the three light spaces were t_2, t_4 and t_6, respectively. If either the scan velocity or the size of the symbol were changed, the magnitude of the individual signal times would also change but relationship between the individual times would remain the same (that is, t_3/t_1 = constant). The binary representation of the character shown in Figure 20 is 0100001 where 0 represents a narrow bar or space and 1 represents a wide bar or space.

One algorithm used for decoding the output of the signal processor is presented in the MSI booklet, *Bar Code Scanning Reference Guide*. The algorithm compares the time to scan neighboring bars. This comparison leads to three possibilities; the second time is greater than, equal to, or less than the first time. These possibilities are assigned the digits 2, 1 and 0, respectively. After a comparison of the times to scan the bars, the times to scan the neighboring spaces are compared.

For the bar code character shown in Figure 20, the time comparisons are as follows:

Time comparison	Digit assigned
$t_3 = t_1$	1
$t_5 = t_3$	1
$t_7 > t_5$	2
$t_4 < t_2$	0
$t_6 = t_4$	1

The resulting number from the time comparisons is 11201. Stored in the decoder portion of the scanning system are tables which relate the numbers determined by the time comparisons to the character represented by the bar code symbol. The bar code symbol in Figure 20 would be decoded as the digit 6 in the Codabar symbology.

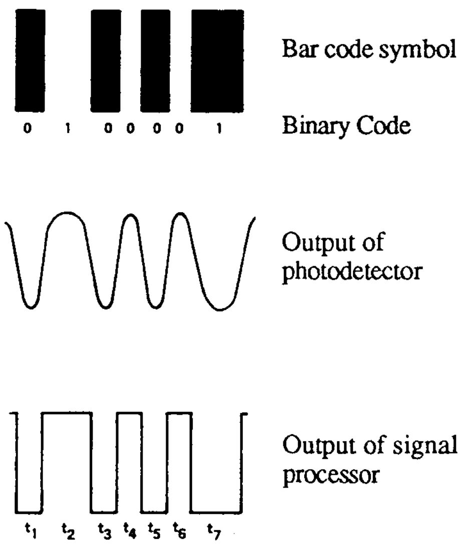


Fig. 20 Bar code decoding. Figure from *Bar Code Scanning Reference Guide*. Copyright © 1980 MSI Data Corporation. Reproduced with permission.

Autodiscrimination is defined by the Automatic Identification Manufacturers (AIM) as the ability of bar code reading equipment to recognize and correctly decode more than one symbology. The decoders produced by Symbol Technologies in Bohemia, NY, can decode the following symbologies from the reflected light signal: UPC/EAN, Two of Five, Interleaved Two of Five Code, Code 39, Code 128 and Codabar.

B. Wand Scanners

Bar code wand scanners or light pens are the most common and popular scanners because of their portability and low cost. They are hand-held contact-scanners which are passed over a bar code to read it. Wand scanners are used to read labels in retail stores, as document readers and in automatic test and quality control equipment.

Figure 21 is a sketch of the MSI Data Corporation wand scanner. Light is emitted from the light source into a fiber optic bundle which directs it to the end of the wand. As the scanner passes over a bar code, the reflected light from the spaces passes through the center opening into a tubular metal shield which contains the light detector (photodetector).

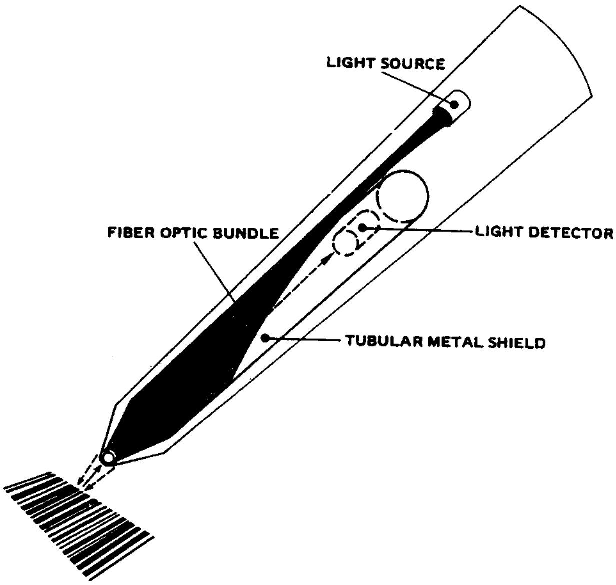


Fig. 21 MSI wand scanner. Figure from *Bar Code Scanning Reference Guide*. Copyright © 1980 MSI Data Corporation. Reproduced with permission.

Most wand scanners use LED's (light emitting diodes) as light sources which emit either visible or infrared light. LED's are semiconductors that produce light at a wavelength determined by their chemical composition. Infrared light scanners are less susceptible to interference from ambient light. The light spot diameter available with wand scanners ranges from 4 mils (0.004 inches) to 10 mils (0.010 inches). Since the wand scanner requires no moving parts, it is a low cost, rugged bar code reader.

To read a bar code with a wand scanner, the operator places the tip of the scanner in the quiet zone ahead of the bar code symbol and in contact with the surface on which the symbol is printed. The scanner is manually moved across the entire symbol in a straight line at approximately constant speed. Scan speeds in the range of 3 inches per second to 50 inches per second can be used to read a bar code. If the scan speed is not maintained relatively constant, the algorithm used in the decoding equipment will not be able to decipher the bar code message.

C. Fixed Beam Scanners

Fixed beam scanners operate on the principle that the bar code symbol to be read is moved in front of the scanner in comparison to wand scanners where the bar code symbol is fixed and the scanner moves across it.

Fixed beam scanners are used to read bar code symbols on cartons moving on conveyor belts at speeds up to 100 feet per minute (20 inches per second). However, since there is only one chance to scan a passing bar code, it is necessary that the orientation and location of the bar code symbol be closely controlled. This is a major limitation of fixed beam scanners.

266652

5a. LADDER-TYPE FORMAT

1 1 1 6 6 6 7 3 2 1 0 0 0 0 0 0 0 0

5b. PICKET FENCE-TYPE FORMAT

1981

5c. OMNI-DIRECTIONAL FORMAT

Fig. 22 Bar code symbol orientation format. Figure from *Scanning Products on the Move*. Copyright © 1983 Automatic Identification Manufacturers, Inc. Reproduced with permission.

When using fixed beam scanners, the orientation of the bar code symbol must be such that the bars and spaces are close to normal to the direction of motion. This is known as the picket fence-type format as shown in Figure 22.

To increase the probability of obtaining a good scan with a fixed beam scanner, the light beam shape is elliptical. The minor axis dimension of the elliptical beam is equal to the width of the narrowest space in the bar code symbol to be read and the major axis dimension is several times that of the minor axis. The major axis of the beam must be aligned to within several degrees of the direction of the bars and spaces. Since the beam covers a larger area of the bar code in comparison to a circular spot, the effect of random printing errors such as ink spots and voids tends to be averaged out.

D. Moving Beam Scanners

The Automatic Identification Manufacturers describe a moving beam scanner as a device that "dynamically searches for a bar code symbol by sweeping a moving light through a field of view."

Most of the moving beam scanners use a helium-neon (He Ne) laser as a light source and therefore are commonly known as laser scanners. The laser produces visible red light of only one wavelength (633 nanometers) which can be focused over long distances. With the aid of a rotating mirror as shown in Figure 17 or another electro-mechanical device, the laser beam spot can scan at a rate of between 35 and 800 scans per second.

In most applications the moving beam scanner will scan the symbol at least five times to achieve a good result. One of the algorithms used in the decoding device to increase the probability of a good read is to compare the results of several scans. If the results agree, the information is sent to a host computer. If the results do not agree, the scanner continues to read until a sufficient number of samples agree or the symbol is deemed unreadable. In some moving beam scanners which scan horizontally, there is a provision for the beam to be deflected a short distance in the vertical direction. This increases the area of the symbol to be scanned and increases the probability of obtaining a good scan even if there are printing defects on the label.

Fixed mounted small laser scanners are used in libraries to read the bar code symbols on library cards and books. Hand held laser scanners are used in retail stores for the rapid reading of labels by sales personnel. Fixed laser scanners are used to read bar code symbols on cartons moving on a conveyor belt at speeds up to 500 feet per second. In this application, the ideal orientation of the symbol is the ladder type format (Figure 22) with the bars and spaces parallel to the direction of motion of the carton. Using a vertical scanner, the entire area of the bar code symbol can be scanned. In case a printing defect exists somewhere on the label, the scanner would have the possibility of locating a region on the symbol where a good scan can be obtained. The omnidirectional format (Figure 22) has the same bar code symbol printed in both the picket fence and ladder formats. If the bar code label is placed randomly on a container, the omnidirectional format still permits the label to be read by a fixed scanner.

IV. BAR CODE APPLICATIONS

A. Supermarket Automation

In 1973, the Universal Product Code was selected by the grocery industry to automate checkout transactions and inventory control in supermarkets. Since then over 90% of items sold in supermarkets have UPC symbols printed on them and the major supermarket chains have installed UPC scanners at checkout counters.

When a supermarket customer arrives at a checkout counter with a UPC scanner, the checker passes each item over the optical scanner which reads the UPC symbol (Figure 23).

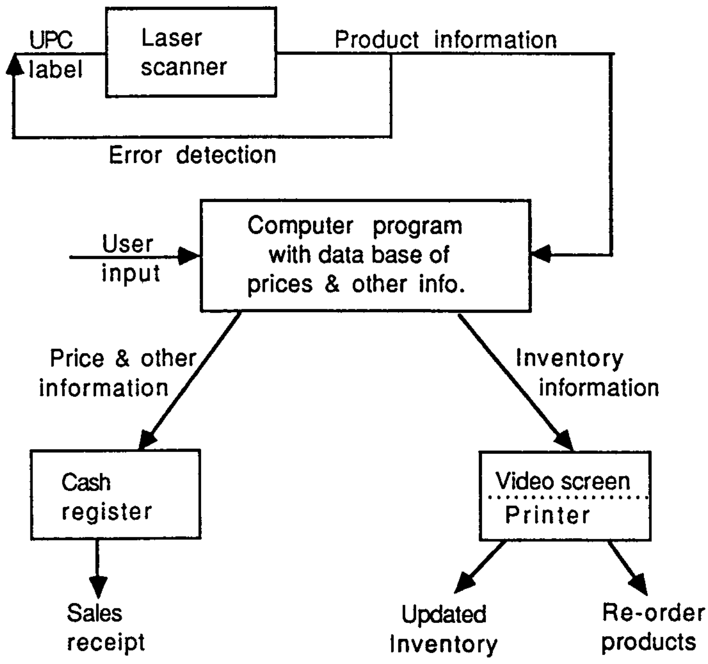


Fig. 23 Supermarket automation system

The information contained in the symbol is decoded and transmitted to a small computer which contains pricing and tax information about all of the items listed in the computer. When the item is located in the computer memory, the computer sends to the cash register at the checkout counter the item's description, price, taxability and food stamp acceptance. This information is displayed to the customer and printed on a sales receipt (Figure 24).

THANK YOU FOR		
SHOPPING WALDBAUMS		
60 WALL ST		
HUNTINGTON NY		
STORE #136	09/04/89	← Date of transaction
NN PANTYHOSE	1.79X	← X indicates taxable and noneligible food stamp item
VOID		
NON FD	-.80X	
FIBER ONE 13	2.05F	
PURTN OIL 32	2.39F	
FRMLNDSKM HG	1.48F	
YOGRT ALMOND	1.29F	
GLAD GAL	1.59X	
WLD CANDY	1.00E	← E indicates taxable and eligible food stamp item
2/1.00		
ALBA MLK 8QT	3.95F	
DOXSEE CLAMS	.89F	
DANNON NF	2.09F	
PEP COOKIES	1.79F	
TONGS	1.79X	
OAT BRAN	1.79F	
NAB OATBRAN	1.99F	
CAROB CLUSTR	1.29F	
TRP GPFTTWST	1.49F	← F indicates eligible food stamp nontaxable item
DOMINO SUGAR	1.49F	
FOLGER DECAF	3.79F	
ANDES TINGAL	1.49E	
HONEYDEW	2.29F	
949 7.89LB		
1LB/ .29		
V CUPN	-2.90F	← V CUPN indicates vendor coupon
TAX	.51N	
TOTAL	34.53	
CASH	40.00	
CHANGE	5.47	
9036 166 5 11.32AM		← Time of transaction

Fig. 24 Supermarket cash register receipt

The information provided the customer on the cash register receipt is very extensive. Knowing the items purchased, a customer can easily locate them on the sales receipt. For example, the entry

FRMLNDSKM HG 1.48F

corresponds to the purchase of a half gallon container of Farmland Skim Milk selling for $1.48. The F following the price indicates that the item is an eligible food stamp, nontaxable item.

The scales for weighing produce are connected to the checkout computer system. A code number is associated with every item of produce sold in the supermarket. When an item is weighed, the checker enters the corresponding code number into the cash register. The weight of the item and its code number are transmitted to the computer which determines its price. This information is then displayed on the sales receipt. The sales receipt shown in Figure 24 includes the purchase of a honeydew melon (code number 949). The melon weighed 7.89 pounds and sold for $0.29 per pound resulting in a sale price of $2.29.

The sales tax rate for taxable items sold in Suffolk County, New York, is 7 1/2%. The cost of taxable items (designated by E and X after their price) on the sales receipt is $6.86 resulting in a sales tax of $0.51.

At some supermarket checkout counters, as an item is scanned a machine generated voice announces its price. In the case where the bar code symbol cannot be read by the scanner due to a printing defect or frost on a carton which came from the freezer section, the checker types the information which is listed on the UPC symbol in human readable form into the cash register .

If the customer has a product refund coupon on which a UPC symbol is printed, the symbol can be scanned. The computer checks to make sure that the item for which the coupon is being redeemed was actually purchased before it transmits the refund information to the cash register. In addition, the computer also checks to make sure that two refund coupons are not being redeemed for the same item.

Some supermarkets provide customers with check cashing privilege identification cards with a UPC symbol on it. When a customer wants to pay the bill by check, the checker scans the identification cards. Credit information about the customer is stored in the computer. If the credit limit of the customer is not exceeded, the computer authorizes the transaction to be paid by check.

At the same time the computer is generating a sales receipt at the cash register, it is also storing information about the items being sold. In this way inventory control is greatly simplified. When an item is sold, it is deducted from the inventory level stored in the computer. If the inventory of a particular item is less than a specified amount, the computer can provide information to the manager to reorder the item. With up-to-date inventory information the on-site stock can be reduced and deliveries can be made "just in time." Reduced on-site stock results in a major cost savings.

The data collected by the computer can provide daily or weekly reports on the performance of the supermarket. In the past these reports were only available monthly or quarterly as the data had to be collected manually. Typical reports generated for supermarket management include:

- product movement
- per capita sales
- checkout counter productivity
- coupon data
- linear footage analysis

With the availability of these management reports, the quality of the services offered by the supermarket to its customers can be increased.

Since the price of an item is stored in the computer, many supermarkets no longer stamp the price on the item itself. This results in major labor savings to the supermarket when stocking shelves and when the price of an item is changed. When there is a price change, only the price in the computer has to be changed. Customers have complained about not having a price on an item as it makes comparison shopping more difficult. In addition, customers must be alert at a checkout counter to make sure that the price stored in the computer matches the price listed in a sales flyer. This is especially true at the start of a sale since prices on a wide variety of items have been changed.

The profit margin for a typical supermarket is 1% of gross sales, while the labor costs associated with the operation of a supermarket correspond to approximately 15% of the operating costs. A small savings in labor costs due to the installation of scanning equipment can result in a substantial increase in profit. For example, a supermarket doing $5M worth of sales annually can expect to make a profit of $50,000 with annual labor costs of $742,500. A 5% decrease in labor costs (due to increased checkout productivity and by not requiring stock clerks to stamp the price on items) would result in an increase in profit of almost 75%.

During the spring of 1990, Automated Checkout Machine Systems (ACM Systems) from Check Robot, Inc. have been installed in many supermarkets in the United States. The ACM System is an automated self-checkout system which replaces traditional clerk-operated checkout lanes with self-service lanes that use laser bar code scanners allowing shoppers to scan and check out merchandise themselves before paying centrally located cashiers. The system is designed to reduce supermarket personnel needs and labor costs by decreasing the number of checkout clerks required. Checkout lane productivity is increased since the lanes can be open all the time unattended.

When using the ACM System, the shopper passes the UPC bar code symbol on each item over the station's laser scanner. As each item is scanned, its description and price is displayed on a video monitor at the front of the lane. A running subtotal is also displayed on the video screen. At the same time the description and price of the item is printed on a sales slip. For produce and other variable bulk weight items, the shopper places the items on a scanner scale and selects the appropriate symbol on the Product Key Pad mounted below the video monitor to complete the transaction. A description of the produce, its weight and price are then displayed on the video screen and printed on the sales slip.

After each item is scanned it is placed on a conveyor belt which transports it through the ACM security system. The security system consists of a series of sensors which detect identifying characteristics of an item such as size and shape. As an item passes through the security system, its identifying characteristics are transmitted to a computer which compares them with the identifying characteristics for the item scanned by the shopper. If the characteristics do not match, the conveyor belt stops and reverses direction, returning the item to the shopper.

After the items clear the security system they are sent to the bagging section at the end of the conveyor belt where the shopper or a supermarket clerk bags them. The shopper then takes the printed sales slip to a central cashier where payment is made. In a typical supermarket using the ACM System, one cashier is responsible for three ACM lanes.

Storage of empty returned containers for beer and soda in states that have container refund laws can be a major problem. To reduce the volume of the containers, machines have been designed which either shred plastic bottles, crush aluminum cans or smash glass bottles. The machine is designed with a laser scanner to read the UPC label on the container before it is destroyed. The scanning system can be programmed to accept only those containers for products sold in the supermarket with the machine. If the container is an acceptable container, the container is destroyed and a refund paid to the customer automatically. If the container is not acceptable, a sign lights up to notify the customer.

B. Postal System

For the Fiscal Year ending September 30, 1989, the United States Postal Service (USPS) distributed 161.6 billion pieces of mail, accounting for 40% of the world's mail. This corresponds to an average of 528 million pieces of mail per business day distributed by 29,100 post offices.

The USPS is the nation's largest civilian employer with 764,000 career employees. As a measure of its productivity, 211,500 pieces of mail were handled per employee per year. In comparison, 61,500 pieces of mail were handled per employee in the Federal Republic of Germany postal system.

Figure 25 presents data on the cost of foreign first class stamps for domestic letters converted to United States currency based upon the foreign exchange rate prevailing on February 12, 1990. The German postal rate is 59.9¢ compared to the USPS rate of 25¢. The land area covered by USPS is approximately 38 times larger than that of the Federal Republic of Germany postal system.

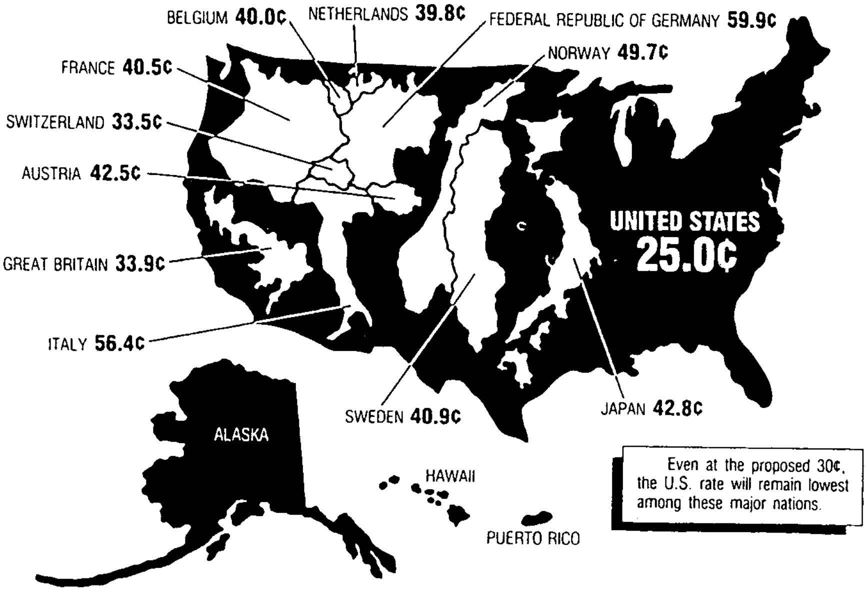


Fig. 25 National first stamp rates and land areas. Reproduced with permission of the United States Postal System.

Measured against the effects of inflation, the cost of mailing a first class letter in the United States has remained relatively stable. In 1971 the price of a first class stamp was 8¢. When the price of a first class stamp increased to 25¢ in 1987, it corresponded to 8.6¢ in terms of 1971 currency when the price is deflated by the Consumer Price Index. Between 1971 and 1987, the cost of a first class stamp ranged between 7¢ and 9.4¢ in 1971 currency according to the *1987 Annual Report of the Postmaster General.*

The FY 89 operating budget of USPS was $38.4 billion. The delivery of mail is labor intensive and over 83% of the operating budget was spent on salaries and benefits. The budget surplus was $61 million corresponding to a profit of 0.038¢ per piece of mail delivered.

From the time a piece of mail is deposited into a mailbox to the time it is delivered, it must be sorted from the mail stream many times. Starting in the late 1950's, the USPS has introduced mechanization and automation into the sorting process to decrease costs and increase productivity. Tabulated below is the percentage of letter mail in FY 89 processed manually, by mechanization and by automated equipment and their respective sorting costs per piece of letter mail.

	% of mail delivered	Sorting Cost
Manual	16	3.5¢
Mechanization	42	1.5¢
Automation	42	0.3¢

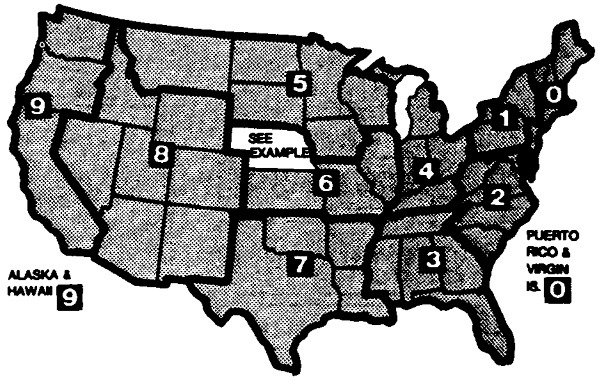
Approximately 20% of the USPS budget is expended in the manual sorting of all types of mail pieces. It is the goal of the USPS to bar code virtually all mail with POSTNET by 1995 to increase the percentage of mail sorted with automated equipment.

In 1775, Benjamin Franklin was appointed the First Postmaster General of the United States by the Continental Congress. As the Post Office entered the 1950's the method of sorting mail was a throwback to colonial times -- the pigeon hole technique -- in spite of the tremendous increase in mail volume.

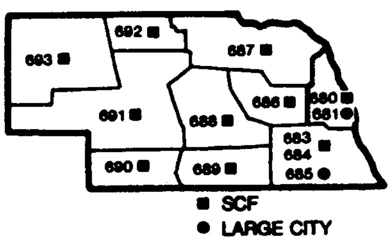
The first semi-automatic mechanized mail sorting machine was introduced into the postal system in the late 1950's. It was the Burroughs Corporation Multi-Position Letter Sorting Machine (MPLSM). The MPLSM was designed to operate with 12 operators sitting at consoles. Mail from a tray automatically passed in front of an operator who read the city and the state of the address. By depressing the appropriate keys on the console keyboard, the operator sorted the letter into one of 277 bins.

After several years of examining various coding systems to facilitate mail processing, the Postmaster General announced that the use of the five digit ZIP (Zoning Improvement Plan) Code would commence on July 1, 1963. The first digit of the ZIP Code designated a group of states as shown in Figure 26. The digits ranged from 0 for the New England States, New Jersey, Puerto Rico and the Virgin Island to 9 for the states bordering on the Pacific Ocean. The following two digits identified a large city or sectional center that was easily accessible to common transportation networks. A sectional center serves the local post offices within the area with the same first three digits of the ZIP Code. As shown in Figure 26, there are a total of 11 sectional centers in Nebraska. The cities of Lincoln and Omaha have their own three digit ZIP Code. The final two digits of the ZIP Code identifies a local post office served by a sectional center or a delivery area of a large city.

The role of the sectional center or processing center is to act as a "middle person" between a local post office it serves and the rest of the post offices in the USPS system. All non-local mail is sent from a post office to the processing center for sorting and distribution nationwide. All incoming mail with the same first three digits in the ZIP Code corresponding to the center is sorted at the center and distributed to the local post office it serves.



a) National area



b) Nebraska

Fig. 26 ZIP Code. Reproduced with permission of the United States Postal System.

When the ZIP Code was introduced, its use was optional by mailers. However, beginning in 1967 second- and third-class bulk mailers were required to presort their mail by ZIP Code. With a major public relations effort by the United States Postal Service for the public to use ZIP Codes when addressing mail to speed its delivery, 97% of all domestic mail was addressed with ZIP Codes by 1978.

The introduction of the ZIP Code permitted increased automation of mail processing at the sectional centers (processing centers). The Multi-Position Letter Sorting Machines were modified to permit the operator to use the ZIP Code instead of the city and state for sorting mail. The first high-speed Optical Character Reader (OCR) was put into operation in the Detroit Post Office in

1965. It was connected to the frame of a MPLSM with its 277 sorting bins. As a letter was passed in front of the Optical Character Reader, the bottom line was read. The letter was directed to one of the sorting bins based on information in the last line of the address. If additional sorting of the mail was required, the address would have to be read again.

In parallel with the development of POSTNET, new automated equipment was being designed and installed in the processing centers. The first computer-driven Optical Character Reader/Channel Sorter (OCR/CS) was installed in Los Angeles in September, 1982. In this machine, the last line of the address on a letter is read. The information is sent to a computer and the POSTNET representation of the ZIP Code is then sprayed onto the envelope. Bar Code Sorters (BCS) are used for subsequent sorting of mail with POSTNET symbols.

The five digit ZIP Code permits letters to be sorted at the processing center for delivery to the local post offices. Once the mail arrives at a local post office, it must be manually sorted twice by the pigeon hole technique (first sorted by route and then sorted by delivery sequence in a given route). This is an expensive, labor intensive operation.

A study was initiated in 1976 to investigate the possibilities of fully automating the sorting of mail at the processing centers down to a carrier route. The study concluded that by expanding the ZIP Code to nine digits (ZIP + 4), mail could be sorted down to a carrier route, or to a particular street, office building or firm. The ZIP + 4 Code was introduced on October 1, 1983.

The ZIP + 4 Code is made up of the original five digit ZIP Code corresponding to a local post office plus four add-on digits. The four add-on digits are separated from the local post office code by a hyphen. The first two add-on digits correspond to a delivery sector of the local post office. The delivery sector could be several blocks, a group of streets, several office buildings or a small geographic area. The last two add-on digits correspond to a segment of the delivery sector. It could correspond to one side of a street, one floor of an office building, a specific department in a firm or a mailbox in a local post office (Figure 27).

With the introduction of ZIP + 4 Code, the USPS ordered an additional 406 Optical Character Reader/Channel Sorters to be delivered between 1986 and 1988. The first 308 were delivered as single line OCR units and the last 98 as multiline readers. The initial 308 Optical Character Readers will be upgraded to include multiline capability by January, 1990. The multiline OCR has the capability of reading all of the lines of an address and determining the ZIP + 4 Code by comparing the address against an internally stored address directory. The POSTNET representation of the ZIP + 4 Code is then jet sprayed on the envelope even if there is no ZIP + 4 Code or an incorrect ZIP Code is on the envelope.

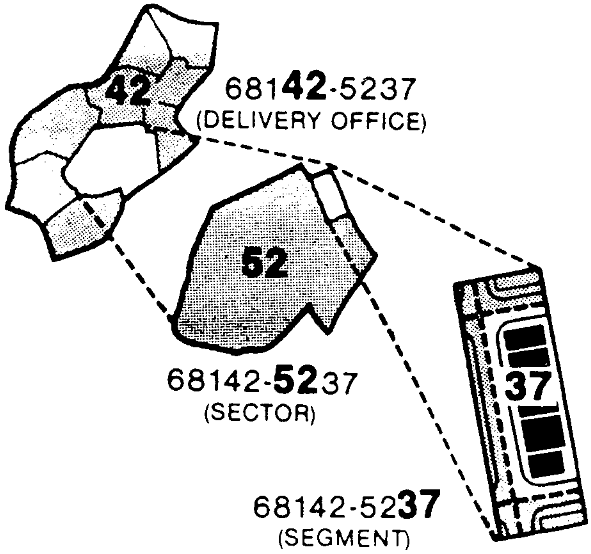


Fig. 27 ZIP + 4 Code. Reproduced with permission of the United States Postal System.

To encourage companies to print the ZIP + 4 POSTNET Code on the envelopes of outgoing mail, USPS offers a reduced postage rate. For companies that send at least 500 first-class letters in a mailing, USPS offers a reduction of 5¢ if the mail is presorted by ZIP + 4 Code and the POSTNET Code is preprinted on the envelope. Bell of Pennsylvania estimates that it saves approximately $15,000 per month using this savings feature. Business reply mail envelopes, such as those used for payment of bills, that are preprinted with the POSTNET Code can be delivered faster and more accurately, resulting in a savings to the company.

To better understand the processing of mail by the United States Postal System, let us consider the operation of a typical mail processing center. For this discussion, performance information about the mail processing equipment was obtained from USPS Publication 150, *Automation and Retail Equipment*, May, 1988.

The United States Postal System Mid-Island Mail Processing Center in Melville, New York, processes all incoming and outgoing mail for Eastern Nassau County and Suffolk County (117, 118, 119) on Long Island and mail arriving at Kennedy and LaGuardia Airports in New York City. Mail arrives at the facility in boxes, mail bags, skids and many other types of containers. The facility processes over 3 million pieces of mail a day.

When the mail arrives at the facility, it is initially separated into letter mail, magazines and newspapers, and cartons. Letter mail is sent to an Edger-Feeder machine where it is dumped on to a conveyor belt. Employees cull out flats (large envelopes and magazines) and small parcels. The mail then passes a rotating roller which removes all mail pieces over 0.300 inches thick. It then falls into a channel conveyor and is transported on edge past a set of pinch rollers that extracts mail over 6.125 inches in height. The remaining letters are sent to the Facer-Canceller machine.

The letters entering the Facer-Canceller have four possible orientations: stamp located in upper right or lower left corner and the address facing the front or the back of the conveyor belt. Each letter passes fluorescent and phosphorescent detectors that look for a postage stamp or meter mark. The newer machines have the ability to detect preprinted Facing Identification Marks (FIM) on mail. FIM is a set of five to seven bars printed on the upper edge of business reply envelopes and cards, and courtesy reply mail. There are four different FIM patterns:

- Business reply mail with prepaid postage, with or without preprinted POSTNET bar codes.

- Courtesy reply mail requiring postage, with or without preprinted POSTNET bar codes.

Figure 16 shows a business reply postcard with a six bar FIM. The horizontal bars on the right hand side of the postcard indicates that USPS must collect postage from the business to which the mail is addressed. When a valid indicium (stamp, meter or FIM) is detected, the letter is postmarked, cancelled and directed to one of four accept stackers, each corresponding to a different orientation of the envelope. The letters are removed from the stackers manually and placed in cartons with the stamp in the upper right-hand corner and the address facing forward. Letters without valid indicia are directed to a bypass stacker. Each of the Facer-Canceller machines has the capability of cancelling 18,000 letters per hour with rates in excess of 24,000 pieces per hour attainable.

The letters are then transported to the Optical Character Reader/Channel Sorter (OCR/CS) where they are manually fed into the feeder unit as shown in Figure 28. The OCR/CS can either be a single line or multiline reader. In a single line reader, the last line of the address which normally includes the city, state and ZIP Code, is read. The machine provides ZIP Code read verification by using a stored address directory to correlate city and state names with the ZIP Code. If the mail piece does not have a pre-printed POSTNET representation of the ZIP Code, an ink jet printer sprays it on the lower right-hand section of the address side of the envelope. A bar code verifier confirms that the bar code on the envelope is the same as the ZIP Codes read by the OCR. The letter is then sent to one of up to sixty sorting channels. If the last line of the address only contains the ZIP Code, the bar code corresponding to the ZIP Code is sprayed on the envelope and not verified with the city and state. If the last line of the address cannot be read -- handwriting, contains other information such as "*Do Not Bend*" or is partially exposed in a window type envelope -- the letter is sent to a reject channel. In a Multiline Optical Character Reader, the entire address on the envelope is read. An address directory stored in a computer is consulted and the ZIP + 4 Code determined. The POSTNET Code representing the nine digit ZIP Code is then sprayed onto the letter and the letter sent to the appropriate channel. The performance of the OCR/CS is 30,000 letters per hour with an accept rate of 60 to 90 percent depending on the mail type. The letters are then dispatched from the OCR/CS to receive additional sorting by Bar Code Sorters (BCS).

Fig. 28 Optical Character Reader/Channel Sorter

The letters rejected by the OCR/CS are sent to the Multi-Position Letter Sorting Machine (MPLSM) as shown in Figure 29. The MPLSM consists of a paneled mainframe with twelve operator consoles attached to one side. The console ledges are manually loaded with faced letter mail. The letters are automatically placed in front of an operator at a rate of 50 to 60 letters per minute, depending on the type of mail being processed. The operator has six tenths of a second to read the ZIP Code and four tenths of a second to depress three keys on the console keyboard. As a result the letter is sent into one of 277 bins according to ZIP Code for dispatch. The performance of the MPLSM is approximately 35,000 letters per hour assuming no jamming of the machine.

Fig. 29 Multi-Position Letter Sorting Machine

A total of eighteen individuals are assigned to the MPLSM. Each individual is assigned to one of the twelve consoles for approximately 40 minutes per hour. When not at the consoles, three individuals are assigned to loading mail to the twelve console positions and two individuals are assigned to checking whether the individual bins are receiving the correct mail. Most of the operators at the consoles of the MPLSM used Walkman type head phones to listen to radio programs.

A supervisor is responsible for each of the MPLSM's. A Video Display Terminal (VDT) displays the ongoing performance of each of the operators. The display present the total number of pieces of mail processed by the operator, the percent error of the letters processed due to incorrect or incomplete keyboarding and other information. The errors reported may be due to operator performance or console malfunction.

Flat mail (newspapers, magazines and large envelopes) cannot be processed by any of the previously discussed machines. Flat mail is sent directly to a Multi-Position Flats Sorting Machine (MPFSM). The MPFSM is designed for four operators; however, the Mid-Island facility has found that it is more efficient to have only three console operators. Flat faced mail up to 3/4 inch thick is picked up by the operator from the feeder conveyor and placed on the induction belt while reading and keying a three digit code corresponding to a portion of the ZIP Code (Figure 30). The flats are distributed to 100 bins for dispatch. Each of the MPFSM's are rated at 8,000 flats per hour. Individuals assigned to the MPFSM's spend approximately 75% of their time at a console and 25% of their time loading into the feeder conveyor.

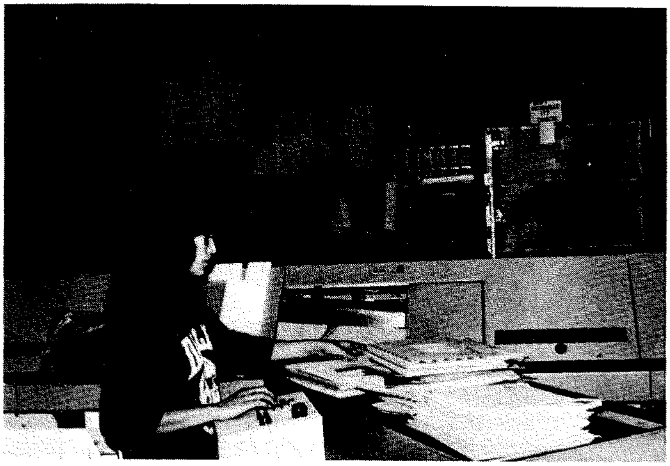


Fig. 30 Multi-Position Flats Sorting Machine

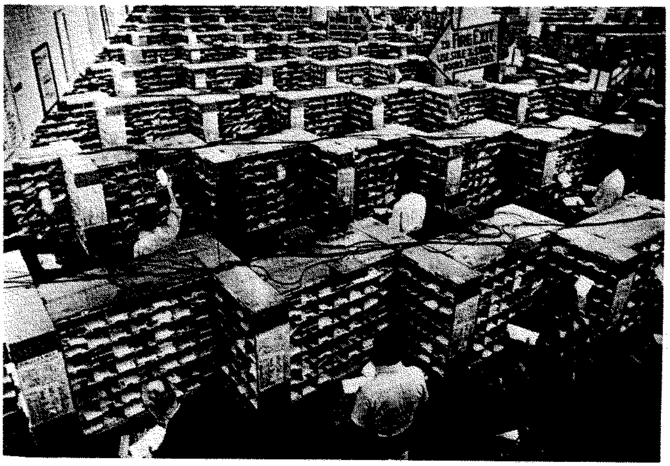


Fig. 31 Pigeon hole type sorters

Mail that cannot be sorted automatically is manually sorted using pigeon hole type sorters as shown in Figure 31. This is the same technique used at a local post office for setting up the mail for a carrier route. If it were possible to bar code all mail with the ZIP + 4 Code, the mail returned from a distribution center to a local post office would be sorted according to carrier route, but not by the sequence that the mail is delivered on the route. During the summer of 1989, the Postmaster General announced that USPS was investigating an eleven digit ZIP Code which would permit mail to be sorted according to its sequence of delivery along a carrier route.

When a person fills out a change of address card in the Eastern Nassau-Suffolk County region, the information is sent to the Mid-Island Mail Processing Center. The information is stored on the computer of a Computer Forwarding System (CFS) machine. Mail that is received by a local post office for an individual who has changed his address is sent to the Mid-Island Center. A CFS operator types the old address on the envelope into the machine, and the computer generates a label with the forwarding address on it.

Approximately 700 employees of USPS work at the Mid-Island Center per shift. Although the facility is highly automated, most of the jobs at the facility require unskilled labor. These include unloading and loading mail into trucks, loading mail into machines, removing mail from the various sorter bins, typing three digits as a piece of mail passes in front of them so that it can be sorted, transporting mail from one location in the facility to another and manually sorting mail that cannot be sorted automatically.

The USPS Engineering and Technical Support Department of the Office is responsible for the development of new automated postal equipment to meet the goal of bar coding all mail by 1995. At the present time, approximately 45% of the first-class mail cannot be read to the ZIP + 4 level by the Multiline Optical Character Readers (MLOCR). The Remote Video Encoding System (REVS) is presently being developed for deployment in the 1990's. The design goal of the system is to apply the ZIP + 4 POSTNET Code on letter mail that cannot be processed by MLOCR, thereby keeping it within the automated mail stream.

In REVS, a video image of the address information on mail rejected by the MLOCR will be taken and stored in memory. The mail piece will also be tagged with a unique bar code identification number on the reverse side of the envelope. The stored video images will be queued to remote video terminals for operators to keyboard the address into a computer which determines its ZIP + 4. The letters will be subsequently processed by modified bar code sorters where the identification number will be read and matched against its ZIP + 4 Code stored in the memory of the computer. The POSTNET Code will then be sprayed on the envelope for use in sorting.

Studies are also underway to determine if the Multi-Position Flats Sorting Machine can be modified so that it can be loaded automatically and whether it will be possible to incorporate a system similar to the Remote Video Encoding System to spray a POSTNET Code on flats.

C. Other Applications

The Computer Systems Division of Harris Corporation manufactures high-performance computers for applications ranging from office systems to flight simulation systems. The computers are designed with high density printed circuit boards which are manufactured in their Fort Lauderdale plant.

In the manufacturing of printed circuit boards, there are up to 20 separate operations during the fabrication and test phases. To provide timely information about the work-in-process at the facility and about quality control, a bar code label is attached to the circuit board during its initial stage of fabrication. Since the circuit board is subjected to employee handling and solder and cleaning operations, a photocomposed metallic label is used and attached with a high temperature adhesive.

A unique seven digit identification number is encoded on the label using Code 39 symbology. The same symbology is used for the bar code label on the identification badge of each of the employees on the assembly line. When a circuit board assembly arrives at a work station, the assembly line worker scans the bar code on his I.D. badge and then the bar code on the circuit board. After the manufacturing operation for that work station is completed, the employee once again scans both bar codes. In addition, the status of the assembly including test results and assembly faults is entered into the manufacturing resource planning system by scanning the appropriate bar code symbol on a menu.

The bar code system permits timely information to be obtained about the status of the work-in-progress on each of the circuit boards under fabrication for production planning meetings and quality control reviews. It also provides productivity data on the employees on the assembly line.

At the Lockheed Aeronautical Systems facility in Burbank, California, there are 25 tool cribs containing tools ranging from rivet guns to high precision gauges. Prior to installing a computerized tool crib inventory management system, each employee used plastic tokens to check out tools. Each employee was given 10 tokens. When an employee requisitioned a tool, the tool crib attendant would accept a token from the employee for each tool checked out and place it on the tool storage rack until the tool was returned. If more than 10 tools were required for a specific job, handwritten tool receipts were required. With a token based system it was difficult to determine tool utilization from a specific tool crib and the total number of tools checked out to an employee from the various tool cribs.

These problems were solved when a computerized system was introduced. With the new system, all of the tools have Code 39 bar code labels attached to them. Employee identification badges have a magnetic stripe on them containing the employee number. When a tool is checked out, the tool crib runs the employee's identification badge through a slot scanner and then scans the bar code on the tool with a non-contact laser scanner to enter the information into the system's computer. The computer notes the time and date of the transaction. When the tool is returned to the tool crib, the employee's I.D. badge and the bar code on the tool are again scanned. If the tool is broken or worn out, its status can be recorded by scanning a menu containing this information.

The computerized system has provided many benefits to Lockheed. The tool-crib attendant can readily determine the number and types of tools assigned to an employee. Since the system records the number of people coming to a tool crib at any given time, its productivity can be determined. As a result, several of the tool cribs are now only open a portion of the day. The system can also alert the tool crib attendant when individual gauges need to be calibrated or tools sharpened based on their total usage.

In most colleges and universities, there is no method of invalidating the identification card of a student who enrolls and then later withdraws or of an employee who resigns. Three large state university systems -- Louisiana State University, University of Nebraska and the University of South Carolina -- are issuing student identification cards with bar coded information on them to ensure that only those entitled to the services and privileges of the university receive them.

The typical identification card is the size of a credit card and contains a photograph of the card holder, an Interleaved 2 of 5 bar code symbol and a magnetic stripe. The bar code symbol represents a total of 12 digits including the card holder's social security number, a status digit (student, employee, spouse, or other), a card sequence digit and a check digit. The first card issued to a student or employee includes the sequence digit 1. If the card is lost or stolen, a new identification card is issued with a sequence digit 2 and the lost card immediately invalidated. In this way, abuses in such applications as library circulation, football ticketing and student government elections can be prevented. The magnetic stripe contains several tracks, each of which may be encoded.

According to an article in the August 1989 issue of *Automatic I.D. News*, the University of Nebraska-Lincoln, with a student population of 23,500, planned to use bar coded identification cards in the Fall 1989 for the following 13 applications:

- Libraries
- Housing and food service
- University bookstore credit card system
- Intercollegiate athletic events
- Registration and records
- Student loan accounts
- Student payroll
- University health center
- Admission to standardized tests

- Student union food service
- Campus recreation including intramural activities and the recreation center
- Student government programs
- Cultural and social programs

Some of the other applications being considered are debit card controllers for the food and cold drink vending machines, washers/dryers, parking and violations, book fines, gasoline purchases, and video games.

When a vehicle enters the Maine Turnpike, the driver is issued a transit ticket with a preprinted Code 39 bar code symbol printed on it. The information contained in the symbol includes the entry location plaza number, vehicle class, number of vehicular axes and a seven digit ticket serial number.

The bar coded symbol is read at the point of entry and the point of departure by laser scanners. The scanned data is initially stored on computer diskettes located at each toll plaza. Once a day the stored information is interfaced with the Maine Turnpike Authority's mainframe computer for data processing. The comprehensive data-base derived from the bar coded ticket information provides toll collector audits, accounting reports, traffic summaries and various management information systems reports necessary for the efficient operation of a toll highway.

The California judicial system is the largest in the United States involving over 220 jurisdictions. The size of the judicial system and the volume of cases handled rank it almost three times larger than the Federal system. The California system has an annual inventory of over 200 million case files with approximately 18 million new court cases filed each year and 12 million cases disposed of (paroles, dismissed cases, etc.). Each case file contains approximately 75 documents.

The SCATSCAN system was introduced by the Judicial Council of California in 1986 to track the location of case files as they moved from one location to another and to collect and compile statistical data about the performance of the court system from approximately 3000 collection points. When a case is filed in a local California court, a 16-character Code 39 bar code label is printed and attached to the case file. Whenever there is a change in status of the case -- such as a new filing, dismissal, court appearance or a guilty plea -- the information is collected. This is accomplished by the court clerk scanning her bar coded identification badge, the case file number and the appropriate bar code for that activity from a menu. A partial listing of the bar code symbols on the menu are shown in Figure 32. The location of the file is always known since every time it is charged out, the identification badge of the recipient is scanned. Evaluators of the system have stated that it has resulted in a five fold increase in efficiency and a ten fold increase in accuracy over key entry.

ADDED TO INVENTORY
CASE PREVIOUSLY FILED
B63

[Scan this code when a case which was filed prior to implementation of the STATSCAN system in the local court is added to the inventory. Scanning this code will require entry of the original filing date.]

JURY TRIAL
E56

[Scan this code after the jury is sworn to try the cause.]

COURT TRIAL - SHORT CAUSE
E57

[Scan this code after the first witness is sworn in a court trial that is estimated to take five hours or less to try.]

COURT TRIAL - LONG CAUSE
E58

[Scan this code after the first witness is sworn in a court trial that is estimated to take more than five hours to try.]

POST DISPOSITION HEARING
E60

[Scan this code for each hearing that is held after a disposition has been entered.]

Fig. 32 Partial bar code menu used by the Superior Court of California. Reproduced with permission of Telxon Corporation.

The Henry Ford Hospital in Detroit is one of the largest health care facilities in the United States with 1000 beds. Prior to 1988, it used a manual system for tracking, billing, and restocking various pharmaceuticals. This required the data entry of over 3.7 million characters per year. In 1988, the hospital introduced three bar code systems for stocking in-patient satellite pharmacies, for patient/charge recapture, and for purchasing/inventory.

Over 1500 different drugs are stored in the hospital pharmacy's main stockroom. The drugs are arranged alphabetically by generic name on the stockroom shelves which are labeled with bar code labels representing the drug item number. When a department requires a drug, it submits a requisition to the main stockroom which specifies the drug item number and quantity and a brief description of the drug. When the requisition is received at the main stockroom, a clerk scans a menu with a laser scanner attached to a hand-held terminal to record the department requesting the drug. The drug item bar code symbol on the shelf is scanned when the drug is removed and the quantity-issued number scanned on the menu. After the requisition is filed, the information is uploaded into the hospital's computer system for inventory and cost control. If a particular drug needs to be reordered, the computer generates a printout for the stockroom.

To track the use of controlled drugs, a computer generated Controlled Drug Administration Record (CDAR) is issued with each controlled substance. Printed on the CDAR in bar code symbology is the CDAR number, the drug identification number, the quantity issued and the nursing unit's name to which the drug was issued. When the drug is given to a patient, a bar-coded Patient Census List is scanned together with the CDAR and the quantity given. This information is updated daily into the hospital's main computer for reporting to the federal government, for patient charge purposes and inventory control. Control substances are stocked at individual nursing stations by minimum and maximum quantities. When the quantity of a specific drug falls below the minimum amount, the computer automatically generates a new CDAR and the main stockroom fills the order.

According to Edward Szandzik, pharmacy project manager at Henry Ford Hospital, "the bar code system has eliminated the need to manually key enter millions of characters per year. As a result, the hospital has saved the equivalent of 1 1/2 full time personnel and increased the accuracy of the inventory data."

Saint Francis Hospital in Topeka, Kansas, is a 311 bed acute care facility. To ensure that critically ill patients receive the correct drug and dosage at the appropriate time, a bar coded point-of-care system was installed in 1988.

Located in a wall mount in each of the patient rooms are a full screen monitor and a portable, hand-held bar code scanner/terminal. When a nurse is ready to administer medication to a patient, she removes the scanner from the wall mount and scans a four digit bar code on her identification badge and the bar-coded wrist band of the patient as shown in Figure 33. Medication for the patient is provided in unit-dose packages. After the unit-dose package is scanned, all of the information is transmitted via radio frequency to the wall unit and from there to the hospital's data processing system. The data processing system verifies that the medication is correct (both drug and dosage). A return signal displayed on the terminal scanner indicates whether the information is correct or whether a problem exists. The Clini Care system enables nurses to document patient care as it is provided. Charge information is automatically captured as a by-product of the documentation process. The bar code symbology used on all of the bar codes is Code 39.

A nurse can display the medical history of a patient using the portable terminal. The hand-held terminal can also be used to enter a patient's vital signs and fluid balances into the hospital's data processing system. Saint Francis estimates that it saves the equivalent of three full-time nurses with the system and provides better patient care.

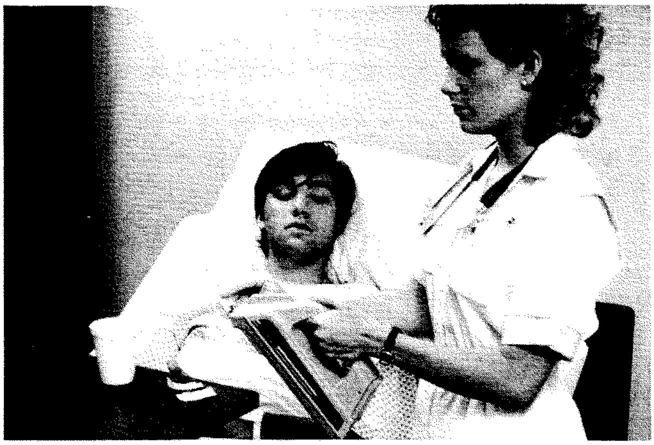


Fig. 33 Hospital application of bar codes. Reproduced with permission of Clini Com, Inc.

Recording television programs with the Panasonic PV-4722 Video ssette Recorder is greatly simplified with a bar code programming system. ; PV-4722 is supplied with a remote contact scanner and a bar code menu. To ord a program, the scanner is used to trace over four Interleaved 2 of 5 bar code nbols on the menu representing the data, the start and stop times and the ;vision channel. As each of the first three bar codes is scanned, a short beep unds to confirm a valid scan. Figure 34 shows a sketch of the Panasonic inner and the four bar codes from the menu which must be scanned to record a ;-hour television program on Channel 11 starting at 12:00 p.m. on the 28th the month. If the scan is not accepted, the bar code is scanned until it is. ter the television channel is scanned successfully, a series of beeps sound to licate that all of the information has been transferred to the VCR by means of infrared beam when the back end of the scanner is pointed towards the VCR l a Transfer Button pressed. The VCR responds with a series of confirmation ;ps and the program information is displayed on the television screen.

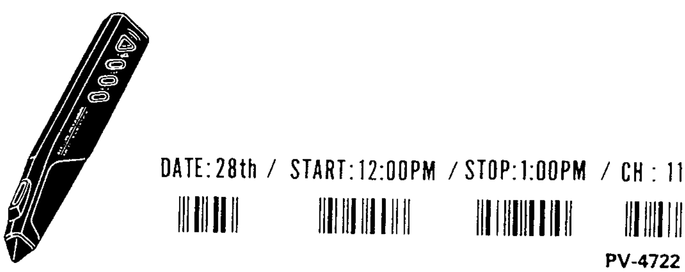


Fig. 34 Panasonic VCR bar code scanner. Reproduced with permission of Matsushita Electric Corporation of America.

Federal Express picks up and delivers over 850,000 packages a day using a fleet of approximately 180 airplanes. One of the key elements in the success of Federal Express is their ability to provide information to a customer about the location, status and movement of a package when requested. To track the movement of each package, a Codabar bar code symbol is on the Federal Express shipping label. The symbol represents the ten digit airbill number plus two additional digits.

When a Federal Express courier picks up a package from a customer, the courier scans the bar code symbol on the shipping label with a Hand Held Products Super Tracker wand scanner as shown in Figure 35. The scanner is shirt pocket size permitting accurate, one hand scanning. It contains a 64K programmable computer which can store 350,000 characters, an alphanumeric keyboard and a two-line display. After scanning the bar code symbol, the courier key enters into the scanner information about the type of service, destination ZIP Code and special handling characteristics. The time and date of the transaction are automatically recorded. When the courier brings the package to the Federal Express van, the scanner is inserted into a sleeve in the van. The sleeve is attached to a computer and a radio transmitter. The information stored in the scanner is transmitted by radio signals to the nearest Federal Express office to be entered into the Federal Express COSMOS tracking system. The package is also scanned when it is brought to the Federal Express office; when it is placed in an outbound hub container; when it arrives at the Federal Express facility in the destination city; when the courier picks up the package for placement in his vehicle, and it is delivered.

Fig. 35 Federal Express employee scanning a shipping label. Reproduced with permission of Hand Held Products.

An interested customer can call Federal Express to find out the time and place when the package was scanned last. For customers who ship more than 20 packages a day, Federal Express permits them to log onto the central COSMOS computer in Memphis and determine the location of the packages themselves.

At the Third International Conference on Book Market Research and Rationalization in the Book Trade, held in Berlin in 1966, the question of the need and feasibility of an international numbering system for books was raised. With the introduction of computers, publishers and book distributors realized that a unique identification number for each book title would be extremely useful for the processing of orders and inventory control. As a result, the International Standard Book Number (ISBN) system was developed and was introduced into the United Kingdom in 1967 by J. Whitaker and Sons, Ltd. and into the United States by the R. R. Bowker Company. The agency responsible for ISBN is the International ISBN Agency located in Berlin.

The ISBN number assigned to a book title consists of ten digits divided into four parts of variable length. The four parts are separated by hyphens or spaces when printed and represent the following:

- Group identifier which identifies the national, geographic or other similar grouping of publishers -- assigned by the International ISBN Agency.

- Publisher identifier -- assigned by the International ISBN Agency.

- Title identifier which identifies a particular title or edition of a title published by the publisher -- assigned by the publisher.

- Check digit

The ISBN number for the book, "Plan Your Estate," by Denis Clifford and published by Nolo Press is 0-87337-050-3. Nolo Press is a small publisher in California and therefore was assigned a five digit publisher identifier number. As a result, the total number of their titles that can be assigned title identifier numbers is 1,000. McGraw Hill Book Company was assigned 07 as its publisher identifier number, and the total number of titles it can assign title identifier numbers is 1,000,000.

The check digit is calculated on a modulus 11 basis with weighting constants of 10 to 2 assigned to each of the nine digits (10 to the first digit of the group identifier and 2 to the last digit of the title identifier). The sum of the products of the individual numbers in the ISBN and their weighting constants is first determined. The check digit is the digit which when added to the sum make it divisible, without remainder, by 11. For the book, "Plan Your Estate," the sum of the products is 217 and therefore the check digit is 3. If the check digit was 10, it would be represented by an X in the ISBN.

With the introduction of bar code scanners into retail book stores, the International ISBN Agency adopted the European Article Numbering (EAN) symbology to represent the ISBN. The 13 digit EAN number consists of the number 978 followed by the first nine digits of the ISBN. The final digit is the EAN check digit. Figure 36 is the EAN bar code which appears on the back cover of the book, "Plan Your Estate." The five digit add-on code includes price information about the book. It should be noted that both the EAN and ISBN numbers are included in the display in human readable form.

51795

9 780873 370509

ISBN 0-87337-050-3

Fig. 36 EAN symbol for the book, "Plan Your Estate."

Library systems use Codabar symbols for checking out and tracking material on loan. The Harborfields Public Library in Greenlawn, New York, issues library cards with a 12 digit Codabar symbol on them. A 15 digit Codabar symbol is attached to all items (books, periodicals, videotapes, CD's, etc.) available from the library.

Figure 37 shows the label attached to the book, "Plan Your Estate." The first four digits (0632) signify the Harborfields Public Library. The following eight digits correspond to the title control number. A two digit copy number or volume number is also included. The final digit is the check digit for the Codabar symbol.

CLIFFORD, DENIS 03/28/90
PLAN YOUR ESTATE
(0) 1989 1ST ED 346.7305 CLI P
0632 03 876642 01 5 (IC=1)

B0632038766420158

Fig. 37 Codabar label in the book, "Plan Your Estate."

When checking out an item from the library, the library card of the individual borrowing the item is scanned first. Then the Codabar label on the item is scanned. When material is returned to the library, only the labels on the items being returned are scanned.

In Finland, magnetic bar code strips are used by the lumber industry to track logs. After a tree is cut down and the branches stripped, a magnetically coded strip is attached to identify it. The type of tree, diameter and cutting instructions are entered into a computer along with the log identification number. The magnetic strips are used to track the logs from the forest to a sawmill. In some cases this operation may take a year. By scanning the bar codes on the logs during their journey, the sawmill can plan in advance for the cutting of each log. The log identification number can also be used to guarantee a specific tree for a specific company which is important when manufacturing fine furniture.

American Airlines is experimenting with bar coded baggage tags to sort baggage after it is checked. Figure 38 shows an American Airline baggage tag for an item of luggage which was shipped from Los Angeles International (LAX) Airport to John F. Kennedy International (JFK) Airport in New York City. The airline industry, represented by the International Air Transportation Association (IATA), determined the standards for bar coded baggage tags. The IATA specified that the bar code symbol representing the destination airport would be its Official Airline Guide (OAG) number between 0001 and 6000 in the Interleaved 2 of 5 Code. The OAG number for Kennedy International Airport in New York City is 2277; for San Francisco International Airport, 4458; and for Pearson International Airport in Toronto, Canada, 5796. The omnidirectional format is used for the bar code symbol which is printed on both sides of the tag.

Fig. 38 American Airlines baggage tag

When baggage is checked in at an airport terminal, a bar coded tag is attached to it. As the baggage travels down the chute behind the airline counter, six laser scanners located around the conveyor belt attempt to read the bar code symbol on the tag. When the symbol is successfully read by any of the scanners, the baggage is automatically sorted to the loading area corresponding to the destination city of the baggage.

In 1985, a terrorist checked luggage containing a bomb aboard an Air India flight which he never boarded. The bomb exploded during the flight and all aboard were killed. To overcome this possibility in the future, international flight regulations now require that a passenger's luggage cannot be on an airplane unless the passenger embarks. The IATA Joint Automated Baggage Handling Working Group is investigating the use of bar coded baggage tags to help enforce this regulation. The baggage tags being considered would be printed out when the passenger checks in and would include passenger ticket information. The bar coded baggage tags would be scanned as the baggage is loaded into the airplane cargo container which would have a permanently attached bar code label on it. If a passenger does not board the aircraft once his baggage is loaded, the baggage can be removed more quickly since the airline could determine the cargo container into which baggage was loaded and in what sequence the containers were loaded onto the aircraft.

One of the most unusual applications of bar codes was discovered by Professor Kirk Jeffrey of Carleton College. Dairy farmers use bar codes to control the mixture and amount of feed for individual cows in a herd. A plastic tag with a bar code symbol on it is strapped around a cow's neck. The cows are fed at individual feeding troughs where only one cow can eat what is in the trough. When the cow approaches a feeding trough, a laser scanner reads its bar code. If the cow has not eaten its prescribed amount for the day, varying kinds and amounts of grain are automatically dumped into the trough. If a cow has eaten its prescribed amount for the day, no more will be forthcoming.

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