Brief History of Barcode Scanning

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Introduction

It is not an overstatement to say that barcodes are nearly everywhere you look—virtually every product you purchase at a supermarket, hardware store, liquor store, book store, or elsewhere carries a universal product code (UPC) barcode printed on the package or an attached label. Most package delivery services, including Federal Express, UPS, and the United States Postal Service, use barcodes on packages for tracking purposes. As a consequence we can track whether the book we ordered from Amazon has shipped, and at any time we please, know where our book is on the route from Amazon to our front door.

Barcode scanners are equally ubiquitous. Scanners are at most check-out counters where we shop. Some of us even carry a barcode scanner with us wherever we go—in the form of an app on our smartphone. One smartphone app can build a grocery shopping list by simply scanning barcodes on empty packages before they go into the recycling bin.

This article provides an illustrated overview of the history of barcode scanning, beginning with the development of the various barcode symbologies, and following through the development of the scanning devices used to read the barcodes. Since the barcode industry has been very competitive, little information was published in technical journals. Inventions were either patented or treated as trade secrets. This article will illustrate the history of barcode scanning based on key patents issued in the field. Figure 1 illustrates by year the number of patents issued that include either of the terms "barcode" or "bar code." Issued barcode patents rose from a trickle in the early 1980s to a high of 265 patents in 2003.

Barcode Symbologies

The first mention of encoding information into printed dark bars and white spaces was disclosed in U.S. patent 1,985,035 submitted by Kermode, Young, and Sparks in 1930. The patent was ultimately issued on 18 December 1934 and assigned to Westinghouse. The invention described a card sorting system for organizing electric bill payments by geographic region, thus simplifying the work of accurately tabulating customer payments.

The first true barcode was a circular "bullseye" symbol invented by Silver and Woodland (see Fig. 2). The two disclosed their invention to the U.S. Patent Office in 1949 and their patent, numbered 2,612,994, was issued on 7 October 1952. The patent contained claims covering a circular bullseye symbol on an item and an apparatus to read the symbol.
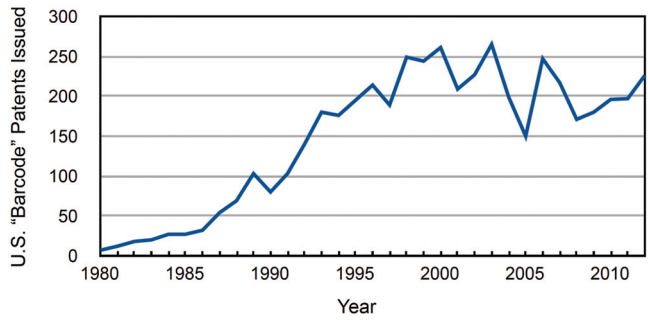
In the late 1960s a group of supermarket chains began to realize efficiencies could be gained with a more automated checkout process. Several checkout methodologies were formulated and subsequently studied resulting in a recommendation to adopt an 11-digit product identification code. This effort ultimately resulted in the formation of the UPC Symbology Committee in March 1971. The committee was charged with selecting a symbology concept and providing a detailed specification for the selected symbology. The Symbology Committee also worked with suppliers of optical readers for the selected symbology.

The symbol ultimately adopted was the UPC symbol found on most products today, as shown in Fig. 3. In the U.S. the leading digits of a symbol, which identify a manufacturer, are
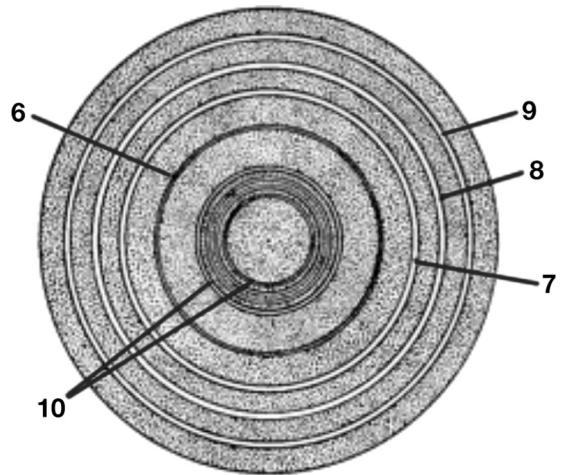
licensed by GS1 US, a private firm responsible for maintaining the assignment of manufacturers' identification numbers. The following five digits are assigned by a manufacturer for each product it produces. The final check sum digit is used to ensure the data integrity of the scanning and decoding processes.

Numerous other symbologies have been developed over the years for other applications ranging from inventory control through military logistics to package tracking by delivery companies. Some of these, such as Code 3 of 9 (aka Code 39) and Interleaved 2 of 5, are purely numeric codes. Others, such as Code 93 and Code 128, are full alphanumeric codes. Examples of these one-dimensional (1D) symbologies are illustrated in Fig. 4.

The need for labels containing ever-increasing amounts of data led to the development of stacked codes and two-dimensional (2D) codes. A complete discussion of these higher information density symbologies is beyond the scope of this article. Examples of higher information density 2D symbologies are shown in Fig. 5.
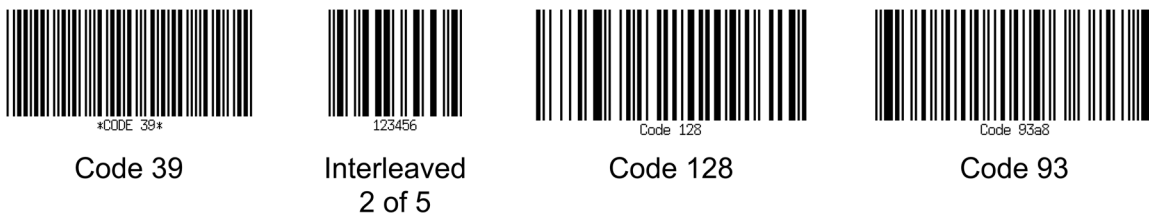
Supermarket Barcode Scanners

In 1971, RCA began the first system test of a bullseye scanner at a Kroger supermarket in Cincinnati, Ohio. This test and others continued through early 1974. The first full-scale implementation of supermarket checkout scanning began at Marsh Supermarkets in Troy, Ohio, when a pack of Wrigley's chewing gum was scanned by a laser checkout scanner on 26 June 1974. The scanner, jointly developed by NCR and Spectra Physics, Inc., is described in U.S. patent 4,064,390 (the "390 patent") issued on 20 December 1977 and assigned to Spectra Physics. One of the original scanners, Spectra Physics serial number 006, from the first Marsh Supermarket installation is now on display at the Smithsonian Institute in Washington, D.C.

These initial supermarket scanners were enormous in comparison to the laser scanners common in today's checkout counters. The scanner was very large and sat directly on the floor. Its scanning window was at the end of a grocery conveyor that sat on top of the checkout counter. The scanner's dimensions were 30 inches high × 12 inches wide ×18 inches

▲ **Fig. 1.** Number of patents issued (including either of the terms "barcode" or "bar code").

Note: LINES 6, 7, 8, AND 9 ARE LESS REFLECTIVE THAN LINES 10.

▲ **Fig. 2.** First true barcode using a circular "bullseye" symbol.

▲ **Fig. 3.** UPC symbol.

▲ Fig. 4. Examples of 1D symbologies.

Code 39 · Interleaved 2 of 5 · Code 128 · Code 93

▲ Fig. 5. Examples of higher information density 2D symbologies.

Code 49 · PDF 417 · QR Code · Datamatrix Code

deep. The scanner is aptly described as being about equally comprised of optics, mechanics, and electronics.

Before beginning a discussion of the optical path through this scanner, is it useful to consider factors involved in scanning a UPC barcode symbol. The UPC symbol was designed so that it could be scanned by a simple X configuration scanning pattern. As a result, the UPC symbol is split into two halves that can be scanned in two separate scanning passes. In order to ensure that the two halves are assembled in the correct order, a check digit and design features such as differing "start" and "stop" bar patterns for the left- and right-hand halves of the symbol are included in the UPC symbology specification. Figure 6 illustrates that the beam labeled "A" scans through the entire left half of the label, while the beam scanning down and to the right ("B") scans through the complete right half of the label. In principle, these two scans produce a scanning signal which allows the entire label to be decoded by the scanning system.

Figure 7 from the "390 patent" illustrates a portion of the optical path in the Spectra-Physics scanner. A 24-facet optical polygon, denoted by "R," provides a mechanism that produces orthogonal horizontal and vertical scan lines on a product (the cube at the top of the illustration). A laser beam entering at the bottom right of the figure is directed by mirror 60 through a slot in the polygon mirror assembly to mirror 82. This mirror subsequently sends the beam to mirror 84, through beamsplitter 86 and lens 88 to mirror 42 and on to lens 90. Lenses 88 and 90 form a relay telescope used in generating vertical scan lines. After lens 90, the beam is deflected by the polygon mirror and reflected by fold mirror 94 through the scanner window 34 to impinge on the product. Light scattered from the barcode label on the product follows a retro-directive path back through the optical system and ultimately impinges on a photodetector (not shown).

Vertical scan lines are generated in a similar manner and follow a similar beam path as the horizontal scan lines, however, each beam from beamsplitter assembly 54, 56, 58 makes two reflections from two separate polygon mirrors. An ingenious arrangement of facet tilt angles of sequential polygon mirrors results in three vertical scan lines for each horizontal scan line. The slots in the face of the polygon assembly are designed so that only one horizontal or vertical scan line passes through the scanning window at any given time.

A large fractional horsepower AC motor rotated the "390" scanner polygon at 3400 RPM producing scanning speeds of 8000 in./min. The retro-directive light collection path utilized aspheric collection optics to minimize spherical aberration and coma. Narrow-band optical filters rejected ambient light. These design features resulted in breathtaking, state-of-the-art, scanning performance. It was possible to literally throw a five-stick pack of chewing gum spinning across the scanning window and have its barcode label decode on the first pass! Now, nearly 40 years later, present day supermarket

checkout scanners are hard pressed to achieve this degree of scanning performance, but they are cheaper, much smaller, and draw substantially less electrical power, all of which add to the bottom line of the supermarket.

Handheld Barcode Scanners

Scanners used in supermarket applications quickly moved to laser scanning due to the high scanning speed and large depth of focus available from such devices. Initial industrial applications of barcodes, such as inventory control and tracking work in process, had significantly lower performance requirements and required lower price points. Initially simple barcode "wands" were used for these purposes. An early barcode wand is described by Turner and Elia in U.S. patent 3,916,184 assigned to Welch Allyn, Inc. (the "184 wand"). The "184 wand" utilized an incandescent bulb or LED and a fiber optic bundle to illuminate the barcode symbol through an opening in the case. A simple two-lens system and photocell or photodiode produced an electrical signal representative of the barcode symbol as the wand was manually scanned across the label. Apertures in the two-lens system controlled the depth of field and field of view (i.e., resolution of the barcode label) of the wand.

Since wands were in contact with the label during scanning, the label became degraded when scanned multiple times. Another common problem with wands was that paper "lint" would accumulate in the entrance opening and degrade scanning performance. To improve on early wands, Bayley of Hewlett Packard suggested the use of a sapphire ball lens in the opening of the wand in U.S. patent 4,855,582. Hewlett Packard's commercial product based on this patent had a compact hermetic electronic package that housed the illumination LED and a photosensor. The highly integrated design was cost effective and very rugged, an important requirement for any handheld device in an industrial or warehouse environment.

The contact nature of barcode wands was a disadvantage in many industrial environments since the label was often read several times during a manufacturing or inventory process, or in package tracking. These applications drove the development of non-contact handheld scanners. An early example is described in U.S. patent 4,560,862, first disclosed to the Patent Office in 1983. The concept of this patent is illustrated Fig. 8. A rotating polygon with concave mirrors scans an image of an incandescent source across a barcode symbol. The illuminated scanning plane is then imaged back along the optical path to a beamsplitter which directs the returning light through a relay lens, aperture stop and field stop to a photodetector. The curved mirrors on the polygon have various radii, thus producing multiple temporally multiplexed focal planes on the photodetector due to rotation of the

▲ **Fig. 6.** Simple X configuration scanning pattern.
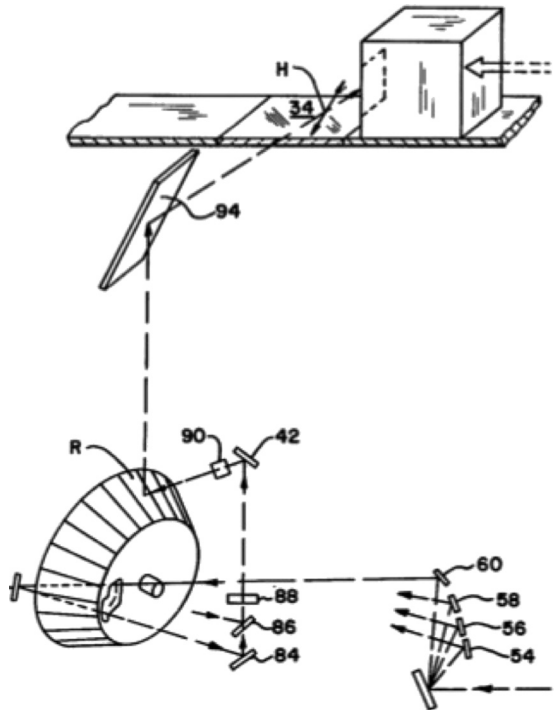
▲ **Fig. 7.** A portion of the optical path in the Spectra-Physics scanner.
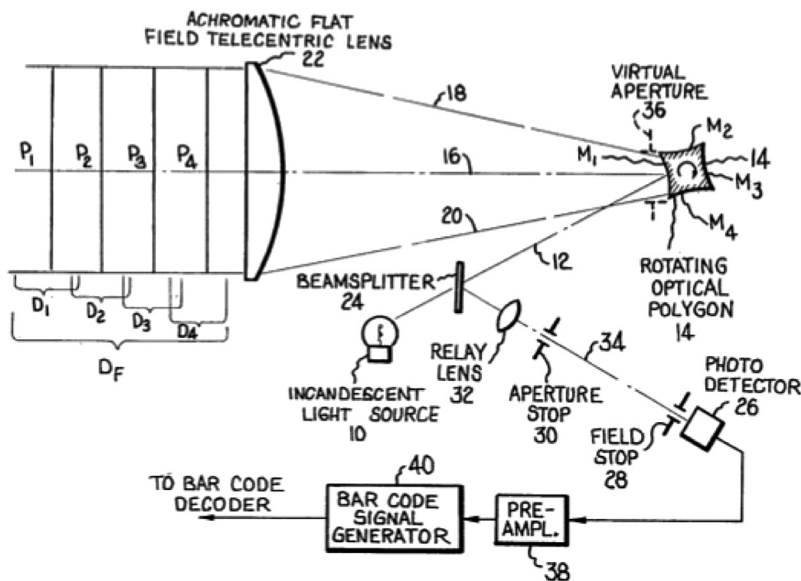
▶ **Fig. 8.** Concept of U.S. patent 4,560,862: A rotating polygon with concave mirrors scans an image of an incandescent source across a barcode symbol.

PSC 2280   STI LS 8500   PSC 5300   Metrologic MS951 (triggerless)

▶ **Fig. 9.** Examples of visible laser diode barcode scanners, in approximate chronological order from left to right. (Courtesy of Cybarcode, Inc.)

polygon. The commercial device utilized eight spherical mirrors on the polygon and was housed in a gun shaped housing for convenient handling, and used a trigger for selection of a barcode label to be read.

Eastman and Boles disclosed the first laser diode based fixed-beam handheld laser scanner to the patent office in 1983, resulting in issuance of U.S. patent 4,603,262 in July 1986. The fixed-beam scanner, similar in size to a child's squirt gun and the first to use surface mount electronics to reduce size and weight, was scanned by the user's wrist motion. The laser diode operated at 780 nm, so its light was not readily visible to a user. Consequently a visible "marker beam" propagated coaxially with the laser beam to enable the user to point the scanner at a barcode label. The scanner had no moving parts other than its trigger button, so it was very rugged and capable of operating after a drop from a second-story window onto a concrete sidewalk with no ill effects.

Both of the above devices were quickly eclipsed by He–Ne-based moving beam handheld laser scanners. U.S. patent 4,409,470 by Shepard, Barkan, and Swartz disclosed a "narrow-bodied" laser bar code scanner that became successful in the early to mid-1980s as Symbol Technologies' LS-7000. The advent of low-cost visible laser diodes quickly led to the availability of rugged handheld laser scanners in the late 1980s and early 1990s, as described in U.S. patents 4,760,248; 4,820,911; and 5,200, 579. In order to avoid the strong patent position of Symbol Technologies in handheld laser barcode scanners, Rockstein, Knowles, and their colleagues invented a "triggerless" handheld barcode scanner as described in U.S. patent 5,260,553. This device automatically began scanning when a barcode symbol was in close proximity. Several examples of visible laser diode barcode scanners are shown in Fig. 9, in approximate chronological order from left to right.

Imaging Barcode Scanners

As higher-density stacked and matrix (i.e., "2D") codes became prevalent, the need for handheld scanners capable of quickly and reliably reading these symbologies became important. Although laser scanner manufacturers attempted to adapt laser scanners to reading 2D codes using two dimensional raster scanning (see, for example, U.S. patent 5,235,167) these devices never achieved the level of performance laser line scanners could achieve reading 1D barcodes. Thus, in the mid-1990s patents began to appear for scanners that imaged the barcode symbol onto a CCD or CMOS array for detection. Broad-area illumination of the symbol was provided using LEDs. Three early examples of handheld 2D imaging bar code scanning technology were disclosed by Wang and Ju in U.S. patents 5,521,366 and 5,572,006, and by Krichever and Metlitsky in U.S. patent 5,396,054.

Details from patent 5,572,006 illustrate the basic configuration of an early handheld 2D imaging barcode scanner. The barcode is illuminated by an illumination array that typically comprised a circuit board, on which LEDs are mounted to broadly illuminate the target area in which the barcode symbol is located. A lens images the illuminated barcode symbol onto a sensor array, which may be either a CCD or CMOS imaging array.

Numerous patents disclosed various techniques for decoding 2D barcode symbologies, but discussion of these techniques is beyond the scope of this short historical article. Readers interested in this aspect of the technology are encouraged to read an excellent text specifically on barcode symbologies: *The Bar Code Book* by Roger C. Palmer. Imaging scanners have several advantages over laser scanners in that they are capable of capturing images of objects and people. Of course, this functionality is dependent on the firmware built into the device. Image quality from a scanner may not rival that of today's low-cost digital point and shoot cameras.

Many of us today routinely carry devices that can serve as 1D and 2D scanners—our smartphones. For example, there are currently at least 100 barcode scanning apps for an iPhone, most of which are available as free downloads. A search of either the Google Play or the Microsoft Marketplace app store lists numerous barcode scanning programs, many of which are also free. Some barcode scanning apps can decode a barcode, search the Internet to find product pricing, list nearby stores that carry the product, and display a map with directions to the store of your choice.

Use of these scanning apps is as simple as pointing your smartphone's camera at the barcode symbol. That's it—no focusing, no careful alignment, and no tapping the screen to capture a picture. The app auto-focuses, auto-recognizes that a barcode is present, decodes the symbol, and finally searches the Internet for available information. Nothing could be simpler; this is truly shopping made easy—and very impulsive!