
# Breaking Down the Barcode

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## Barcode Reading Basics and How to Choose the Right Barcode Reader

A barcode is a visual expression of data designed specifically to be read by machines. They store information such as model number, serial number, or product history. The first barcodes expressed this data in the width and spacing of parallel black bars and white spaces. These are called 1D (one-dimensional) barcodes and are still incredibly ubiquitous today.

However, more recently, barcodes that are composed of boxes, or cells, were created in order to store vast quantities of data. These barcodes, because they are rows and columns in a grid, are called 2D barcodes (although they are not comprised of bars, as such). From their humble beginning as an unloved patent back in 1952 to today, when virtually every industry uses barcoding, understanding barcodes, how they work, and how to best integrate them into your application is vital.

## 1D (Linear) Barcodes

There are two main types of barcodes. The "traditional" barcode, 1D or linear, is made up of parallel black lines and white spaces of various widths. A barcode reader, scanner, or a computer calculates the width of the bars as well as the widths of the spaces between them to "read" the barcode. 1D barcodes are the most common type of barcode, used in industries spanning clothing retail to the United States Military. Within the category of 1D barcodes, there are many different kinds developed for various industries, with particular qualities that make them well-suited to the type and quantity of data needed. Here are some examples of common 1D barcodes and the industries that utilize them:

**CODE128** (material handling)


**POSTNET** (US Postal Service)


**UPC-A** (US retail)


**INTERLEAVED 2 OF 5** (industrial)


**CODE 39** (military, government agencies)

## Composition of a 1D Barcode

The graphic below demonstrates the elements of a 1D barcode (Code 128).


*Colors added for identification purposes only.

**Bar** – black line that composes the barcode's stored information. In the simplest codes, bars are two sizes: wide and narrow. This information is translated into binary when read by the sensor. However, other symbologies are more complex and involve various bar and white space widths.

**Quiet zone/margin**—blank space around the barcode that the computer/scanner/reader recognizes to mark the beginning and the end of the code. Virtually every type of 1D barcode requires a quiet zone.

**Start and Stop Code** – specific combination of bars and spaces indicate either the beginning or end of the barcode. Data – where the encoded data is contained.

**Check digit (or checksum)** — typically located at the end of the barcode, guards against reading erroneous data. Using the check digit calculation formula, which takes the previous barcode data, should produce a number that matches the check digit. If the two numbers match, the code is accepted.

**Human Readable Code** – digits or characters that can be read by humans, they serve no purpose in reading the barcode.

## Stacked Linear Barcodes

Multiple 1D codes can be stacked closely on top of one another as a way to fit more data into a small space. Thus, they are called "stacked linear barcodes," and they take advantage of ever-increasing reader capacity to read dense information.

**PDF417**

**GS1 DataBar Stacked**

(01) 0 9501101 53000 3

# 2D Barcodes

While the 1D barcode is a good way to store some information, the 2D barcode contains data stacked both horizontally and vertically, greatly increasing the possible characters stored in the code as well as the density and complexity of information.

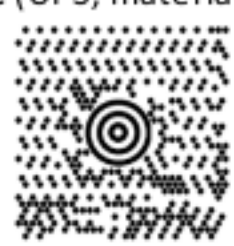
Functioning similarly to the check digit on 1D barcodes, the 2D barcode has built-in error correction. In many 2D codes, data is coded three times over, giving the reader a far better chance of correctly scanning and processing the information. Among the most common types of 2D barcode are:

**DataMatrix** (automotive, electronics, USPS)

**Aztec** (travel tickets, vehicle registration documents)

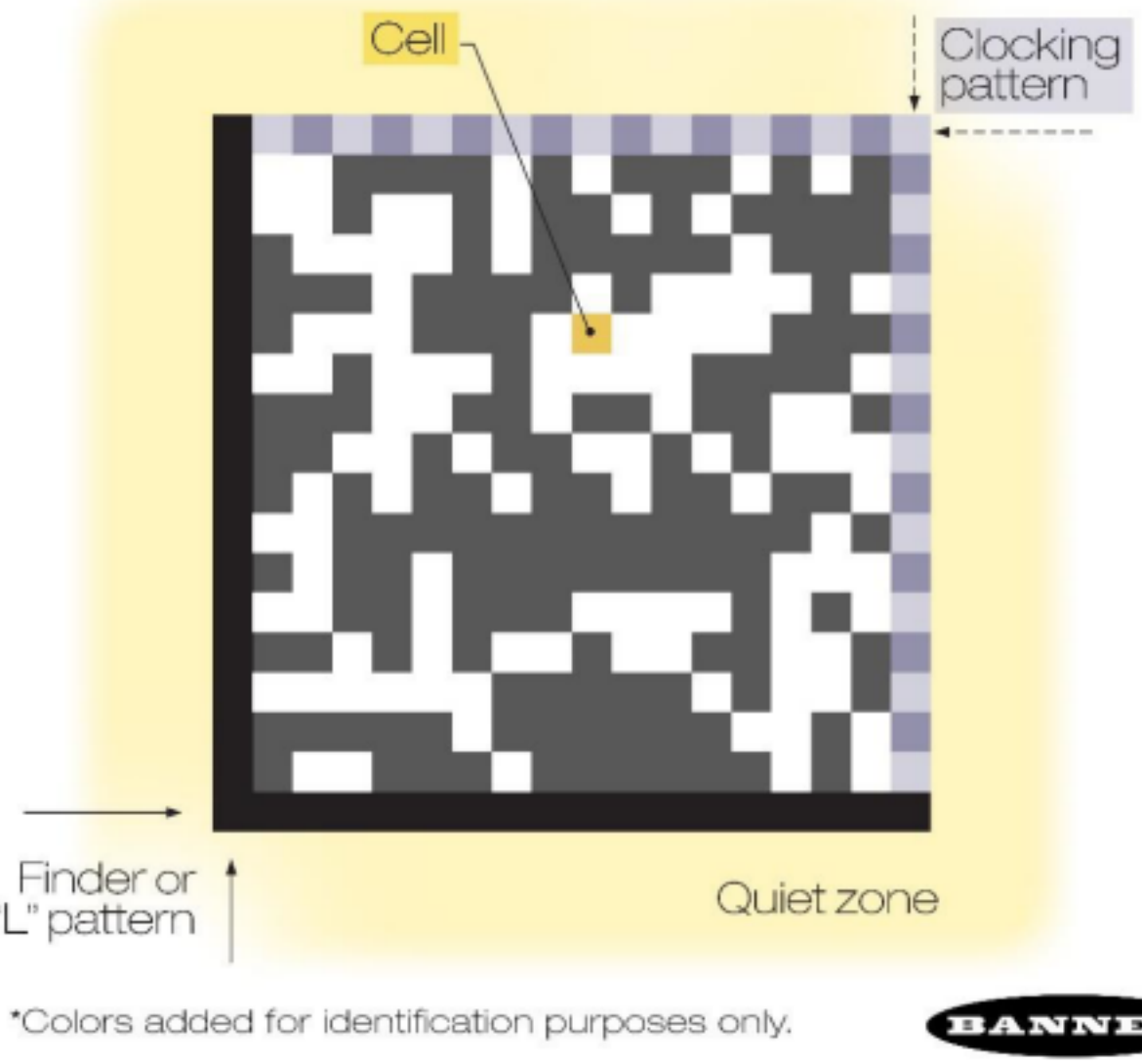
**QR code** (automotive, commercial marketing)

**Maxicode** (UPS, material handling)



## Composition of a 2D Barcode

The graphic below demonstrates the elements of a 2D barcode (DataMatrix).




**Cell**—the 2D code's equivalent to the bar, the cell is the square inside of the code that is filled black. The code is read by mapping the white and black spaces.

**Quiet zone**— same function as 1D barcodes, but it must surround all four sides of the 2D code, not just extend from the left and the right.

**Finder (or "L") pattern**— L-shaped mark on the outside edge of two sides of the 2D code. The finder pattern enables the reader to orient to the proper way to read the code.

**Clocking pattern** — on the opposite sides of the finder pattern, alternating black and white boxes inform the reader of the width of the cells inside the code and its overall size (the number of columns and rows that make up the square).

## Barcode Printing and Labeling Methods

Typically, barcodes are printed onto adhesive labels or directly onto product packaging. There are two main ways to print the code using traditional printing methods: inkjet/dot matrix printing, and thermal printing.

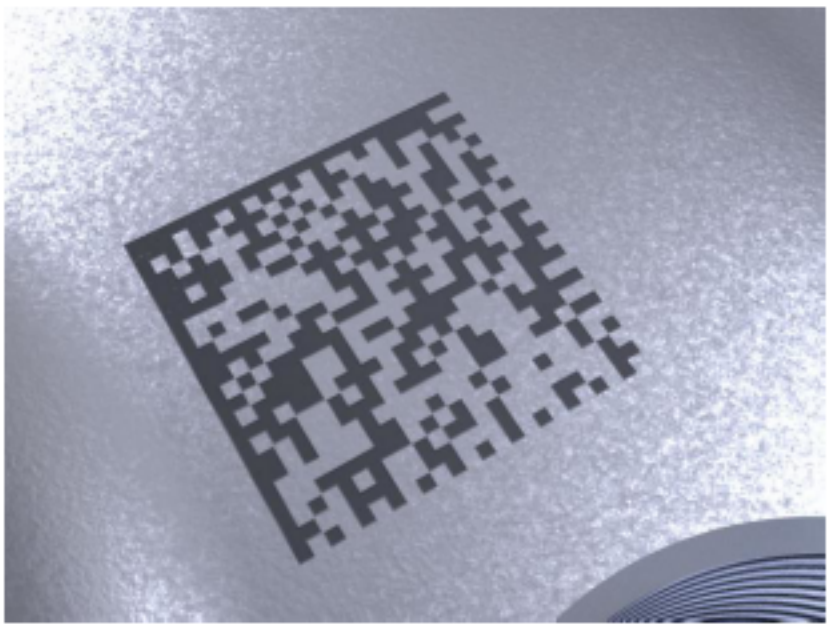
**Inkjet/dot matrix**— involves spraying the ink out in tiny droplets onto the label. There is some risk of splatter, smudging, or blurring of the barcode as it prints, and thus increased risk of loss of image quality over time.

**Thermal printing**—involves heating up a ribbon which then melts directly onto a label. Temperature and conditions of the workspace are important to consider, as overheating of either the printer or the thermal paper before, during, or after printing can affect the image.

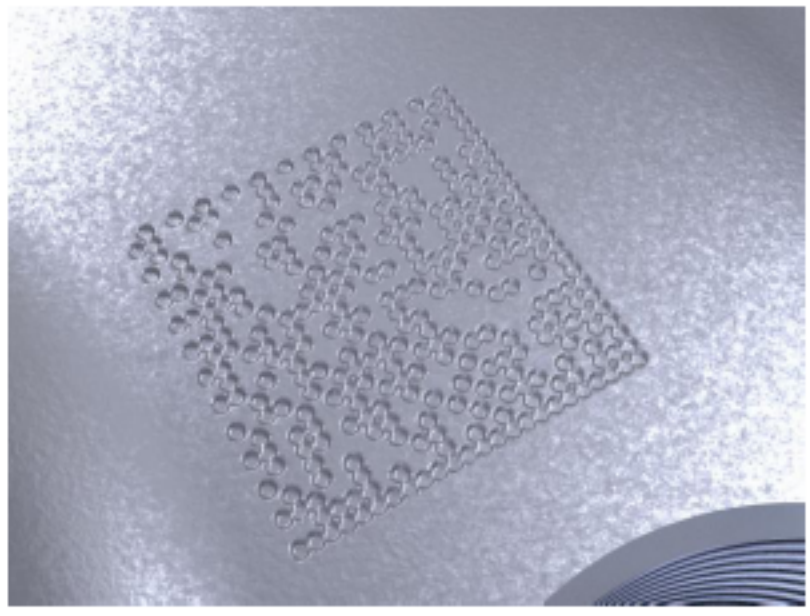
## Direct Part Marketing (DPM)

When barcodes are not printed on labels, they can be marked directly onto the surface of the product. This is more common in the automotive and electronics industries, as their products tend to be more durable and/or need to be tracked throughout their lifecycles for liability reasons. Direct part marking (DPM) is a longer-lasting alternative to print barcoding and involves one of a few different methods. Because of the nature of the products, industries, and information that's stored, 2D DataMatrix or QR codes are most commonly used when directly marking.

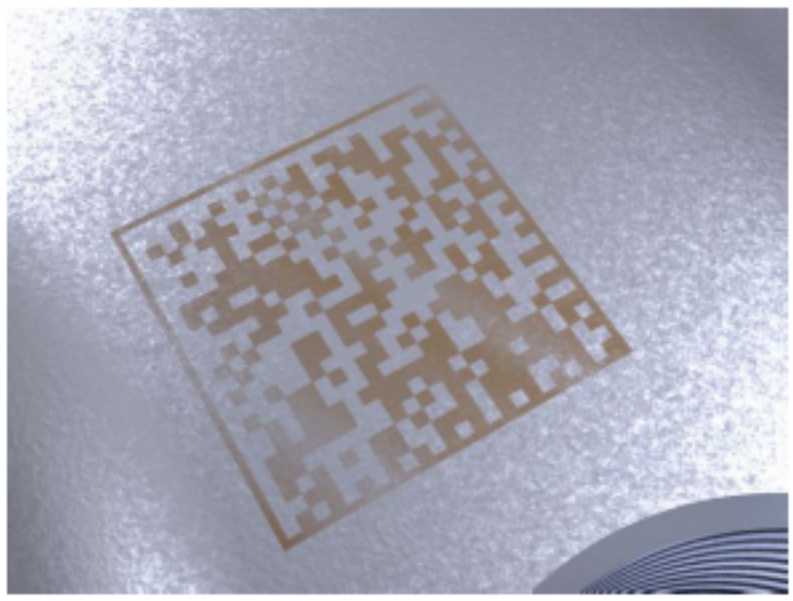
**Laser marking** – fiber lasers are used to engrave the barcode directly on the part.



**Dot peen** — divots are pressed into metal using a stylus to create the barcode.



**Electrochemical etching** – a sodium-based solution is combined with a low-volt electrical current, which, when charged, dissolves the metal. A stencil is used to create the shape of the barcode.



# Types of Barcode Readers

## Laser Scanners

Laser scanners have long been the standard reader for 1D barcodes. A rotating mirror wheel inside the scanner directs the laser beam from left to right across the barcode. A photodiode translates that reflected light into an electrical current, creating an analog signal, which is finally converted into a digital signal. They do not require an additional image processor or lighting to assist with contrast. Since a laser produces collimated light, the beam can travel great distances without being diverged, thus enabling the scanner to accurately read barcodes from greater distances than imager-based readers. The relative simplicity of the scan (as well as the speed of light as it travels) means they are capable of scanning at high speeds, with some products capable of up to 1,300 scans per second.


However, laser scanners have limitations. The most glaring is that they are only able to read 1D barcodes—1D codes are still the most prevalent today, but that is changing. Laser scanners are also only capable of reading codes from left to right, meaning that barcodes must always be perfectly oriented to the scanner if the scanner is going to read them. The internal rotating mirror wheel and other moving parts make the scanner more susceptible to issues requiring maintenance and repairs.

## Imager-Based Readers

Imager-based readers are the most versatile reader option as they can read both 1D and 2D barcodes and are much more difficult to confound with damaged or incorrectly oriented barcodes. They operate with what is essentially a digital camera that takes a picture of the barcode. Then a microprocessor runs an image-processing algorithm which locates and "translates" the code.

The percentage of barcodes that read successfully in an automated manufacturing process is called the read rate. The power of image analysis algorithms often leads to higher read rates than those of laser scanners, making the

manufacturing process more efficient. The various steps in this process are largely what make the reading time slower than that of laser scanners. They can be more costly than laser scanners, but many companies bundle all the necessary components into a single system.


Like the difference between high- and low-quality digital cameras, resolution is the key element of an image reader's capacity to recognize and read a barcode. The higher the resolution, the greater the ability to read smaller codes and search larger areas. While resolution is important, it is also necessary to select the right lens for the application to get an optimal image. The most common types of lenses are C-mount and S-mount, which usually require manual focus adjustment upon installation. Industry leaders are also producing image readers with mechanical or liquid lens autofocus, which control the movement of the lens without human interaction to focus the image.

## How to Implement Barcodes and Barcode Readers

Now that you have an overview of barcodes and how they work, here and the questions to consider when looking at implementing barcodes and readers into your application:

### What kind of barcodes do I need?

This should be the first question you consider. If you're starting from the beginning and first need to decide which type of barcode you want to use, think about the information you want to store—is it more basic, or will you need more complex data, like tracking lifecycles? How much space will be available on your products for the barcode, and what can be done to make it easier to read?

For example, while a 2D code can pack more data in a square space, a 1D code with bars that travel around the circumference of a round part may be easier to read because all the information is available at the same angle.

After determining your barcode type, you can weigh the other factors, such as scan speed or orientation, to determine what sort of reader will be best for your application. If your application involves any 2D codes, an imager-based reader is necessary to be able to read them.

## What is the size of the barcode?

The size of the barcode--the width of the smallest bars or cells, especially--will impact a reader's ability to reliably and accurately read the code. If your application involves small parts, such as the assembly of electronics, the codes printed on those parts will be very small. Because of their high-resolution capabilities, imager-based readers work best for reading small codes. The larger the code, the easier it will be to be read at a greater distance or over a greater range of distances.

## How quickly do the barcodes need to be read?

For fast-paced applications where time is of the essence, it is important to know the unique benefits and considerations of different kinds of readers and codes. If you are trying to select a barcode type for use in a fast-paced application, a 1D barcode may better suit your needs. Although they cannot store the same density or complexity of information as the 2D codes, they are easy to quickly read with a laser scanner or imager-based reader. This is ideal for applications where speed directly translates to increased production, such as beverage packaging verification.

That said, if you want to store more than basic information in your code, an imager-based reader is the only type of reader that can read a 2D code. In addition, they are much less likely to be confused by a damaged code—saving considerable time and money by preventing unplanned downtime due to misreads or an inability to read altogether.

## How far away is the target? What are the mounting concerns?

If there will be a great distance between the barcode and the reader, a long-range reader must be selected, with a longer focal length and more powerful illumination. It's also important to consider the best type of reader given the application; will there be a human operator? Will it be in a fixed position? Many companies offer different mounting options and even handheld models for both laser scanners and imager-based readers.

Additionally, if a laser scanner is mounted in a position that is not perfectly oriented to the barcode, it will not be able to correctly read the code. An imager-based reader can read barcodes with any orientation and are capable of reading codes at various distances, ideal for applications where reading distance or position will change.

## What kind of communications do I need?

Most industrial implementations send data from the barcode reader to a PLC over an Industrial Ethernet protocol, such as Ethernet/IP, Modbus/TCP, or PROFINET. If the PLC does not have Ethernet available, then a serial protocol like RS-232 or RS-422 may be the best option. When the data is being sent to a computer, rather than a PLC, this is often done over Ethernet TCP/IP, serial, or USB communication.

If an operator is manually entering data into PC software, they may want a USB reader that can emulate a USB keyboard and enter the data exactly as if it were being typed on a physical keyboard.

# Putting It All Together

As we've learned, there is no one "perfect" barcode type or reader. The varieties in both enable endless possibilities for using barcodes effectively in new applications. Keeping in mind key factors like barcode type, scanning speed, and versatility will help orient you to the best reader for every challenge.

Contact us for more information about barcodes or to discuss your application with an expert.