

QR Code® Essentials

The QR Code is used in fields as diverse as manufacturing and mobile marketing.

Since its introduction in 1994, the QR Code® has gained wide acceptance in such diverse industries as manufacturing, warehousing and logistics, retailing, healthcare, life sciences, transportation and office automation.

Now with the explosive growth of smartphones, the QR Code is also being used in mobile marketing and advertising campaigns as a fast and effective way of connecting with customers and providing end-user content, including Web links, mobile coupons, airline boarding passes, etc.

Successful implementation of the QR Code in any of these fields requires a knowledge of certain basic information about both the QR Code itself and the technology associated with it.

What is the QR Code?



QR Code

The QR (Quick Response) Code is a two-dimensional (2-D) matrix code that belongs to a larger set of machine-readable codes, all of which are often referred to as barcodes, regardless of whether they are made up of bars, squares or other-shaped elements.

Compared with 1-D codes, 2-D codes can hold a larger amount of data in a smaller space, and compared with other 2-D codes,

QR Code Essentials

the QR Code can hold much more data still. In addition, an advanced error-correction method and other unique characteristics allow the QR Code to be read more reliably and at higher speeds than other codes.

Like written language, barcodes are visual representations of information. Unlike language, however, which humans can read, barcodes are designed to be read and understood (decoded) by computers, using machine-vision systems consisting of optical laser scanners or cameras and barcode-interpreting software. The rules with which a barcode is constructed (its grammar) and the character set it uses (its alphabet) are called its symbology.

How 1-D barcodes work

There are two basic types of barcode symbologies: one-dimensional, or linear, and two-dimensional.

One-dimensional (1-D) barcodes contain information in only the horizontal direction.

One-dimensional (1-D) barcodes, such as the Universal Product Code (UPC) commonly seen on the price tags and packages of products in a retail or grocery store, consist of a series of vertical bars and spaces. They are classified as one-dimensional because the information contained in them is communicated only by the difference in their horizontal dimension—the width of the bars and spaces—and their position from left to right.



To barcode-reading software, both of these 1-D barcodes are identical. Changing the height of the bars does not change the information they contain.

Differences in the second, vertical dimension of the bars and spaces—whether they are taller or shorter—does not matter; all that counts is how wide they are and what order they are placed in.

From 1-D to 2-D codes

After the commercial introduction of 1-D barcodes in 1966, they quickly gained widespread acceptance. In time, however, demand grew for new types of codes that could hold more

QR Code Essentials

information and use more character types, yet occupy a smaller space.

Attempts were consequently made to increase the amount of data contained in barcodes by increasing the number of bars or creating multiple-barcode layouts. These efforts, however, resulted in a larger barcode area, complicated reading requirements and increased printing costs.

To solve these problems, two-dimensional (2-D) codes were developed, first as stacked barcodes, which repeat the same linear symbology vertically, and then as matrix codes, composed of small, symmetrical elements arranged in a square or rectangle.







Multiple-barcode layout

2-D stacked barcode

2-D matrix code

Because 2-D matrix codes contain information in both the horizontal and vertical direction, they met the need for high data density and small size, yet further improvements were still to follow, including those introduced by the QR Code.

The following table summarizes the features and characteristics of some typical 2-D codes.

		QR Code	PDF417	DataMatrix	MaxiCode
					
Developer		DENSO Wave	Symbol Technologies	RVSI Acuity CiMatrix	UPS
Type		Matrix	Stacked barcode	Matrix	Matrix
Data capacity	Numeric	7,089	2,710	3,116	138
	Alphanumeric	4,296	1,850	2,355	93
	Binary	2,953	1,018	1,556	-
	Japanese, Chinese or Korean characters	1,817	554	778	-
Main features		Large capacity, small size, high-speed scanning	Large capacity	Small size	High-speed scanning
Main applications		All categories	Office automation	Factory automation	Logistics
Standards		AIM, JIS, ISO	AIM, ISO	AIM, ISO	AIM, ISO

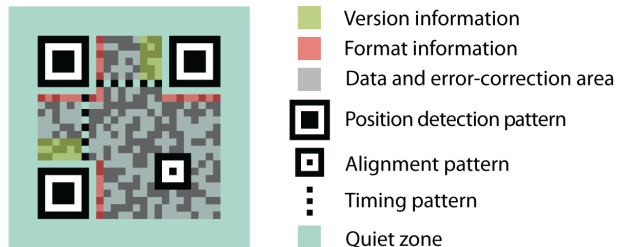
How the QR Code works

The QR Code is a 2-D matrix barcode that contains information in both the horizontal and vertical dimension.



Unlike 1-D barcodes, the QR Code is a 2-D matrix code that conveys information not by the size and position of bars and spaces in a single (horizontal) dimension, but by the arrangement of its dark and light elements, called “modules,” in columns and rows, i.e. in both the horizontal and vertical directions.

Each dark or light module of a QR Code symbol—a specific instance of a code—represents a 0 or 1, thus making it machine-intelligible.



The QR Code modules perform several functions: Some contain the actual data itself, while others are grouped into various function patterns that improve reading performance and allow symbol alignment, error correction and distortion compensation. The timing pattern lets the scanning device know the size of the symbol. There is also a required “quiet zone,” a four-module-wide buffer area containing no data, to ensure that surrounding text or markings are not mistaken for QR Code data.

Conventional 2-D matrix codes required a considerable amount of time to be spent searching a symbol’s code to determine its angle of orientation, position (x and y coordinates) and size.

To address this problem, the QR Code was designed with special position-detection patterns located in three corners of each symbol. The patterns have a symmetrical scan-line ratio of 1:1:3:1:1, which allows them to be scanned from any direction

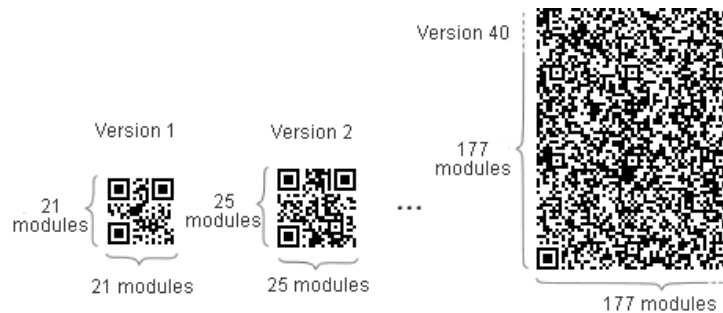
QR Code Essentials

within a full 360 degrees. In addition, the positional relationship of the patterns allows quick access to the relevant angle, position and size information contained in the code's periphery.

As a result, the QR Code does not require lengthy code searching, enabling reading speeds 20 times faster than those of conventional matrix codes. Also, searching the position-detection patterns can be performed by the scanning hardware, further increasing overall speed by allowing image reading and data processing to be carried out simultaneously.

QR Code Symbol Versions

QR Codes can be generated in 40 different symbol versions, from 21 x 21 modules (version 1) to 177 x 177 modules (version 40).



Each higher symbol version has 4 additional modules per side (16 additional modules per symbol), and can contain a proportionally larger amount of data. The maximum amount of data that can be contained by a given symbol is determined by its version, type of characters and error-correction level.

QR Code Error Correction

The QR Code's powerful error-correction capability is achieved by adding Reed-Solomon codes, a widely used mathematical error-correction method, to the original data. This allows a QR Code symbol to be read even if it is dirty or damaged.

Four levels of error correction are available. The higher the level, the greater the error correction, but also the larger the QR Code version.

QR Code Essentials

Error-Correction Level	Approximate Amount of Correction
L	7%
M	15%
Q	25%
H	30%

When selecting the level of error correction, environmental conditions as well as the desired size of the QR Code symbol need to be taken into account.

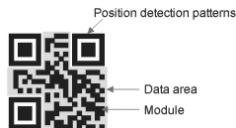
For example, Level Q (25% error correction) or H (30%) may be required for factories or other applications where the QR Code is likely to become dirty or damaged. For clean environments and codes containing a large amount of data, Level L (7%) may be selected. In general, Level M (15%) is most frequently used.

QR Code Benefits

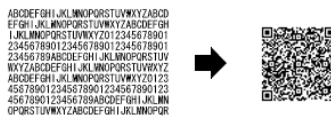
The QR Code's unique design gives it many unique advantages and benefits, including:

The QR Code combines fast scanning, high-capacity storage and small size.

Fast, omnidirectional scanning: Position-detection patterns in three corners of a symbol allow the QR Code to be read from any angle within 360 degrees, eliminating the need to align the scanner with the code symbol. The position-detection patterns also eliminate any background interference, ensuring stable high-speed reading.



High-capacity data storage: A single QR Code symbol can contain up to 7,089 numerals—over 200 times the amount of data as a traditional 1-D barcode.



A QR Code symbol of this size can hold 300 alphanumeric characters.

QR Code Essentials

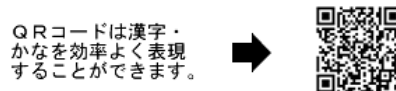
Small size: A QR Code can hold the same amount of data contained in a 1-D barcode in only one-tenth the space.



Error correction: Depending on the error-correction level chosen, a QR Code symbol can be decoded even if up to 30% of the data is dirty or damaged.



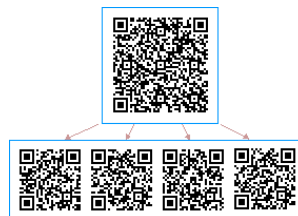
Many types of data: The QR Code can handle numerals, alphabetic characters, symbols, Japanese, Chinese or Korean characters and binary data.



Distortion compensation: A QR Code symbol can be read even if its image is on a curved or otherwise distorted surface.



Linkability (Structured Append): A QR Code symbol can be divided into up to 16 smaller symbols to fit long, narrow spaces. The smaller symbols are read as a single code, regardless of the order in which they are scanned.



The four QR Code symbols in the bottom row contain the same data as the symbol in the top row.

Direct Marking: The QR Code's high degree of readability under low-contrast conditions allows printing, laser etching or dot-pin marking (DPM) of a symbol directly onto a part or product.

Uses of the QR Code

Although the QR Code was originally designed to track automotive components and systems through the manufacturing process and distribution supply chain, it has rapidly spread to virtually every other area where traditional barcodes are used, as well as some entirely new ones.

Typical applications include:

- **Manufacturing**
 - Product traceability
 - Process control
 - Order and time tracking
 - Inventory and equipment management
- **Warehousing and logistics**
 - Item tracking
- **Retailing**
 - Point-of-purchase product identification
 - Sales management
 - Inventory control
- **Healthcare**
 - Medical records management
 - Patient identification
 - Medication tracking
 - Equipment and device tracking
- **Life sciences**
 - Specimen tracking
- **Transportation**
 - Fleet management
 - Ticketing and boarding passes
- **Office automation**
 - Document management
- **Marketing and advertising**
 - Mobile marketing
 - Electronic tickets, coupons, payments and loyalty programs

The use of the QR Code in mobile marketing allows direct communication between advertisers and smartphone users.

The newest and most innovative uses of the QR Code are in marketing and advertising.

QR Code Essentials

Mobile marketing has been very popular in Japan, Korea and the Netherlands for several years, and has recently seen rapid growth in North America, where the QR Code is increasingly appearing in print and online advertising, as well as on signs, billboards, posters, business cards, clothing and other items. By scanning a QR Code with a smartphone, consumers can be connected to a relevant Web page or receive targeted marketing messages such as a special offer, discount coupon, product or store information, etc.

In addition, scanners are now available that are specially designed to read a QR Code displayed on the LCD screen of a smartphone. The code can contain a user's electronic ticket or coupon, electronic payment information, loyalty-program identification, etc.

Generating QR Codes

As the inventor of the QR Code and owner of the QR Code trademark, DENSO Wave Incorporated has allowed the patents for the code to be freely available to the public. Consequently, many websites now feature online QR Code generators or downloadable code-generating software.

Such code generators and software are not certified by the International Organization for Standardization (ISO), however, so there is no way of telling if they adhere to the relevant ISO Standard 18004, which is based on the DENSO Wave patent. As a result, the code symbols they create may not be readable by all devices or the reading quality may be reduced.

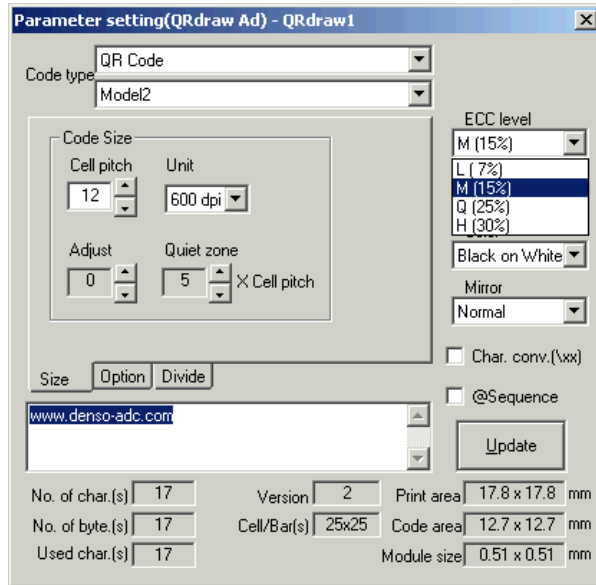
(An easy test is to create the same code symbol with two or more online generators and compare the results. Differences in the arrangement of the modules—similar to the differences in language translation—will be immediately apparent.)

Of particular concern is the fact that non-ISO-compliant code generators do not determine the minimum printable size of a given QR Code symbol. If a symbol is printed at a size that is below the ISO-specified minimum—which takes into account the amount of data contained in that symbol, the symbol version and the resolution of the printing device—readability will be dramatically reduced.

To ensure that a QR Code will be readable by the highest percentage of devices, only code-generating software compliant with ISO Standard 18004 should be used.

QR Code Essentials

Using QR Code-generating software that is not ISO compliant can be especially problematic if the QR Code is to be read by smartphones, whose quality may greatly vary. Also, the QR Code-reading software used by smartphones, like code-generating software, is not necessarily based on ISO specifications.



Only ISO-compliant QR Code-generating software can ensure maximum symbol readability and specify the minimum printable size for a given symbol.

To ensure that a QR Code will be successfully read by the highest percentage of devices, therefore, it is essential to use code-generating software offered only by a reputable manufacturer who can be trusted to comply with ISO specifications.

Reading QR Codes: 5 things to look for in a 2-D scanner or terminal

Ergonomic scanner designs reduce operator fatigue, increase productivity.

1. High-speed reading: Faster scanning and the ability to scan barcodes from a distance increase operator efficiency. Look for devices with advanced CCD scanning technology, which enables even high-density or poorly printed barcodes to be read at high speed and from a distance.

QR Code Essentials

2. Ease of use: Lightweight, ergonomic designs, featuring large display screens and easy-to-hold grips, reduce operator fatigue, a key factor in productivity.

3. Durability: In the field, hand-held scanners and terminals are vulnerable to harsh environments and rough handling, including being bumped or dropped. Devices featuring rugged, drop-resistant construction and resistance to water and dust protect your equipment investment.

4. Long battery life: Scanners are available with power-saving features that result in longer operating time, eliminating frequent, time-consuming battery changes.

5. Experience and reputation of the manufacturer: Look for a manufacturer that has established itself as an industry leader and innovator, and whose products have stood the test of time.

About DENSO ADC

DENSO ADC is the Americas sales arm of DENSO Wave Incorporated, which pioneered CCD technology and invented the revolutionary QR Code. DENSO Wave is among the world's largest manufacturers of mobile data capture systems.

The company offers a wide range of advanced-technology, handheld 1-D and 2-D terminals and scanners. These products feature industry-leading, lightweight, ergonomic designs; rugged technology that can stand up to the roughest handling and harshest environments; superior resistance to water and dust exposure; power-saving advantages that enable longer operating time; communication via Bluetooth, USB, serial or keyboard interfaces, or live communication via 802.11b, Bluetooth or GPRS; and lower cost of ownership.

For more information, visit the DENSO ADC website at www.denso-adc.com.

DENSO ADC is a brand of DENSO Corporation, headquartered in Kariya, Aichi prefecture, Japan. DENSO is a leading global automotive supplier of advanced technology, systems and components in the areas of thermal, powertrain control, electric, electronics and information and safety. Its customers include all the world's major carmakers. Worldwide, the company has more

QR Code Essentials

than 200 subsidiaries and affiliates in 35 countries and regions (including Japan) and employs approximately 120,000 people. Consolidated global sales for the fiscal year ending March 31, 2011, totaled US\$37.7 billion. Last fiscal year, DENSO spent 9.3 percent of its global consolidated sales on research and development. DENSO common stock is traded on the Tokyo and Nagoya stock exchanges.

In North America, DENSO employs 13,000 people with consolidated sales totaling US\$6.4 billion for the fiscal year ended March 31, 2011.