QR Code Encoding

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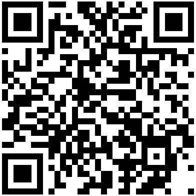
Introduction

- Reference:
  `www.thonky.com/qr-code-tutorial/introduction`



- The QR code format was created in 1994 by Japanese company Denso-Wave, a subsidary of Toyota that manufactures anto components.
- The standard is defined in ISO/IEC 18004:2006.
- The use of QR codes is license-free.

Version and Error Correnction Level

- Different sizes give different versions.

Version	Size
1	21 by 21 modules
2	25 by 25 modules
⋮	⋮
40	177 by 177 modules

- QR codes include error correction (EC): create some redundant data that will help a QR reader accurately read the code even if part of it is unreadable.

EC level	EC Capability
L	Recovers 7% of data
M	Recovers 15% of data
Q	Recovers 25% of data
H	Recovers 30% of data

Step 1: Data Analysis

Determine which QR Code Mode should be used.

- **Numeric mode**: decimal digits 0 through 9.
- **Alphanumeric mode**: decimal digits 0 through 9, as well as uppercase letters, and the symbols $, %, *, +, -, ., /, and : as well as a space. All of the supported characters are listed in the left column of this alphanumeric table.
- **Byte mode**: characters from the ISO-8859-1 character set.
- **Kanji mode**: double-byte characters from the Shift JIS character set.
- ...

Step 2: Data Encoding

- First: choose the error correction level.
- Second: determine the smallest version for the data.

Version	EC	Numeric	Alphanumeric	Byte	Kanji
1	L	41	25	17	10
	M	34	20	14	8
	Q	27	16	11	7
	H	17	10	7	4
2	L	77	47	32	20
	M	63	38	26	16
	Q	48	29	20	12
	H	34	20	14	8

Example: phrase HELLO WORLD with level H error correction.

Step 2: Data Encoding

- First: choose the error correction level.
- Second: determine the smallest version for the data.

Version	EC	Numeric	Alphanumeric	Byte	Kanji
1	L	41	25	17	10
	M	34	20	14	8
	Q	27	16	11	7
	H	17	10	7	4
2	L	77	47	32	20
	M	63	38	26	16
	Q	48	29	20	12
	H	34	20	14	8

Example: phrase HELLO WORLD with level H error correction.
The smallest version is version 2.

Step 2: Data Encoding

- Third: add the mode indicator

Mode	Indicator
Numeric	0001
Alphanumeric	0010
Byte	0100
Kanji	1000

- Fourth: add the character count indicator.
  - Count the number of characters in the original input text, then convert that number into binary.
  - The length of the character count indicator depends on the encoding mode and the QR code version that will be in use.
  - To make the binary string the appropriate length, pad it on the left with 0s.

Step 2: Data Encoding

Table : Length of character count indicator

Mode\Versions	1 – 9	10 – 26	27 – 40
Numeric	10 bits	12 bits	14 bits
Alphanumeric	9 bits	11 bits	13 bits
Byte	8 bits	16 bits	16 bits
Kanji	8 bits	10 bits	12 bits

- Example: encode HELLO WORLD in a version 1 QR code in alphanumeric mode, the character count indicator must be 9 bits long. The character count of HELLO WORLD is 11. In binary, 11 is 1011. Pad it on the left to make it 9 bits long: 000001011. Put this after the mode indicator from the previous to get the following bit string: 0010 000001011.

Step 2: Data Encoding

- Fifth: encode using the selected mode.
- To take alphanumeric mode with data phrase HELLO WORLD as an example.
- Break up the string into pairs: HE, LL, O , WO, RL, D.
- Create a binary number for each pair.
- H→17, E→14, $(45 * 17) + 14 = 779 \rightarrow 01100001011$ (11 bits). Odd number → 6 bits.

Table : Table of Alphanumeric Values

0	0	**1**	1	**2**	2	**3**	3	**4**	4	**5**	5	**6**	6
7	7	**8**	8	**9**	9	**A**	10	**B**	11	**C**	12	**D**	13
E	14	**F**	15	**G**	16	**H**	17	**I**	18	**J**	19	**K**	20
L	21	**M**	22	**N**	23	**O**	24	**P**	25	**Q**	26	**R**	27
S	28	**T**	29	**U**	30	**V**	31	**W**	32	**X**	33	**Y**	34
Z	35		36	**$**	37	**%**	38	*****	39	**+**	40	**-**	41
.	42	**/**	43	**:**	44								

Step 2: Data Encoding

Table : Table of Alphanumeric Values

<table>
<tr><th>Mode Indicator</th><th>Character Count Indicator</th></tr>
<tr><td>0010</td><td>000001011</td></tr>
<tr><th colspan="2">Encoded Data</th></tr>
<tr><td colspan="2">01100001011 01111000110 10001011100
10110111000 10011010100 001101</td></tr>
</table>

- Sixth: break up into 8-bit codewords and add pad bytes if necessary.
  - Determine the required number of bits for this QR Code. `http://www.thonky.com/qr-code-tutorial/error-correction-table`
  - Add a terminator of 0s if necessary (up to 4 0s).
  - Add more 0s to make the length a multiple of 8.
  - Add pad bytes if the string is still too short. (11101100 00010001)

Step 3: Error Correction Coding

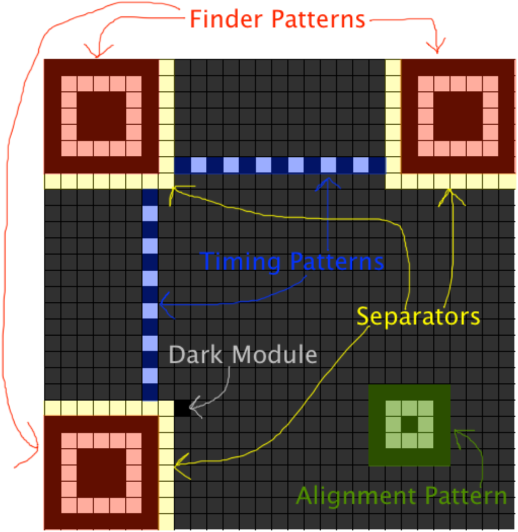
- Data codewords may be broken into blocks depending on the version and error correction level.
- For each block of data codewords, error correction codewords are generated accordingly.
- Expert John Burkardt will give the details about error correction.

Step 4: Structure Final Message

- Interleave the Blocks
  - take the first data codeword from the first block
  - followed by the first data codeword from the second block
  - followed by the second data codeword from the first block
  - and so on until all the data codewords are placed
  - take the first error correction codeword from the first block
  - followed by the first error correction codeword from the second block
  - followed by the second error correction codeword from the first block
  - and so on until all the error correction codewords are placed
- If only have one block, simply place the error correction codewords after the data codewords.
- Add remainder bits if necessary.

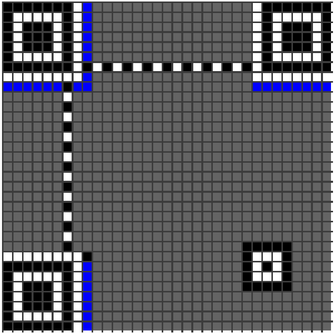
Step 5: Module Placement in Matrix

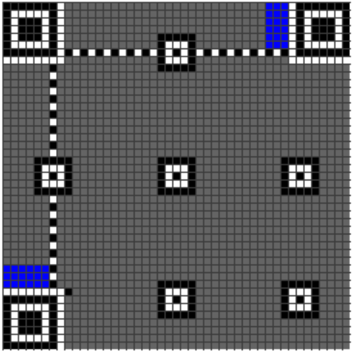
QR codes must include function patterns.



Step 5: Module Placement in Matrix

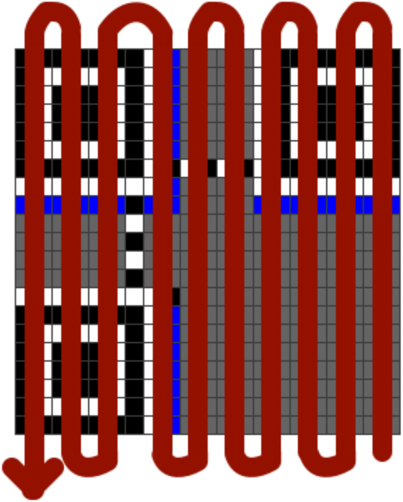
Reserve the format information area and the version information area.





Step 5: Module Placement in Matrix

Place data bits.



Final 2 steps

- Step 6: Data Masking
    - A mask pattern changes which modules are dark and which are light according to a particular rule.
    - The purpose of this step is to modify the QR code to make it as easy for a QR code reader to scan as possible.
- Step 7: Adding Format and Version Information
    - create the format and version strings, then place them in the correct locations in the QR code.

Output the Final Matrix

Add the Quiet Zone.