

Structure Final Message

In the error correction coding (error-correction-coding) section, the Reed-Solomon error correction process was explained. You should now have the data codewords and their corresponding error correction codewords. As mentioned in the previous step, larger QR codes require you to break the data codewords into smaller blocks, and generate error correction codewords separately for each block. When this is the case, the data blocks and error correction codewords must be interleaved according to the QR code specification. This page explains the interleaving process in detail.

Step 1: Determine How Many Blocks and Error Correction Codewords are Required

The error correction table (error-correction-table) shows how many data blocks and error correction codewords per block are required for each version and error correction level.

For Smaller Codes, Use Data and Error Correction Codewords As-Is

Please note that smaller QR codes only consist of one block of data codewords, with one set of error correction codewords for that block. In this case, no interleaving is necessary. Simply place the error correction codewords after the data codewords and move on to the next step, module placement in matrix (module-placement-matrix).

Break Up Larger QR Codes

On the error correction coding page, I showed an example using a 5-Q code. The error correction table says that a 5-Q code's first group consists of 2 blocks, with 15 data codewords per block, and the second group consists of 2 blocks, with 16 data codewords per block. Here again is the table shown on the error correction coding page that showed the 5-Q code broken up into groups and blocks.

Group Number	Block Number	Data Codewords in the Group
Group 1	Block 1	(codeword #1) 01000011 (codeword #2) 01010101 (codeword #3) 01000110 (codeword #4) 10000110 (codeword #5) 01010111 (codeword #6) 00100110 (codeword #7) 01010101 (codeword #8) 11000010 (codeword #9) 01110111 (codeword #10) 00110010 (codeword #11) 00000110 (codeword #12) 00010010 (codeword #13) 00000110

		(codeword #14) 01100111 (codeword #15) 00100110
	Block 2	(codeword #16) 11110110 (codeword #17) 11110110 (codeword #18) 01000010 (codeword #19) 00000111 (codeword #20) 01110110 (codeword #21) 10000110 (codeword #22) 11110010 (codeword #23) 00000111 (codeword #24) 00100110 (codeword #25) 01010110 (codeword #26) 00010110 (codeword #27) 11000110 (codeword #28) 11000111 (codeword #29) 10010010 (codeword #30) 00000110
Group 2	Block 1	(codeword #31) 10110110 (codeword #32) 11100110 (codeword #33) 11110111 (codeword #34) 01110111 (codeword #35) 00110010 (codeword #36) 00000111 (codeword #37) 01110110 (codeword #38) 10000110 (codeword #39) 01010111 (codeword #40) 00100110 (codeword #41) 01010010 (codeword #42) 00000110 (codeword #43) 10000110 (codeword #44) 10010111 (codeword #45) 00110010 (codeword #46) 00000111
	Block 2	(codeword #47) 01000110 (codeword #48) 11110111 (codeword #49) 01110110 (codeword #50) 01010110 (codeword #51) 11000010 (codeword #52) 00000110 (codeword #53) 10010111 (codeword #54) 00110010 (codeword #55) 11100000 (codeword #56) 11101100 (codeword #57) 00010001 (codeword #58) 11101100 (codeword #59) 00010001

	(codeword #60) 11101100
	(codeword #61) 00010001
	(codeword #62) 11101100

Notice that the error correction table says that for each block, a 5-Q code must have 18 error correction codewords. Now that error correction coding (error-correction-coding) has been explained, the error correction codewords for the above data can be calculated.

There are four blocks, so four sets of 18 error correction codewords should be generated. The following is an updated table that shows the data correction codewords of each block converted into a list of integers, and the 18 error correction codewords generated for each block.

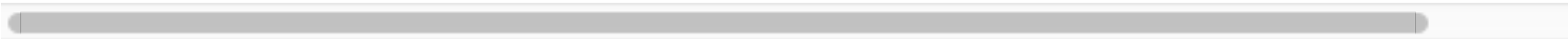
Group Number	Block Number	Data Codewords in the Group	Data Codewords as Integers
			Error Correction Codewords for the Block
Group 1	Block 1	(codeword #1)	Data Codewords from the left, as Integers: 67,85,70,134,87,38, Error Correction Codewords (show how these were calculated (msg_coeff=67%2C85%2C70%2C134%2C87%2C38%2C85%213 199 11 45 115 247 241 223 229 248 154 117 154 111 86 11
		01000011	
		(codeword #2)	
		01010101	
		(codeword #3)	
		01000110	
		(codeword #4)	
		10000110	
		(codeword #5)	
		01010111	
		(codeword #6)	
		00100110	
		(codeword #7)	
		01010101	
		(codeword #8)	
		11000010	
		(codeword #9)	
		01110111	
		(codeword #10)	
		00110010	
		(codeword	

	#11) 00000110 (codeword #12) 00010010 (codeword #13) 00000110 (codeword #14) 01100111 (codeword #15) 00100110	
Block 2	(codeword #16) 11110110 (codeword #17) 11110110 (codeword #18) 01000010 (codeword #19) 00000111 (codeword #20) 01110110 (codeword #21) 10000110 (codeword #22) 11110010 (codeword #23) 00000111 (codeword #24) 00100110 (codeword #25) 01010110 (codeword #26) 00010110	Data Codewords from the left, as Integers: 246,246,66,7,118,134,242,7,38,86,22,198,199,146,6 Error Correction Codewords (show how these were calculated (msg_coeff=246%2C246%2C66%2C7%2C118%2C134%2C24 87 204 96 60 202 182 124 157 200 134 27 129 209 17 163 163

		(codeword #27) 11000110 (codeword #28) 11000111 (codeword #29) 10010010 (codeword #30) 00000110	
Group 2	Block 1	(codeword #31) 10110110 (codeword #32) 11100110 (codeword #33) 11110111 (codeword #34) 01110111 (codeword #35) 00110010 (codeword #36) 00000111 (codeword #37) 01110110 (codeword #38) 10000110 (codeword #39) 01010111 (codeword #40) 00100110 (codeword #41) 01010010 (codeword #42)	Data Codewords from the left, as Integers: 182,230,247,119,50,7,118,134,87,38,82,6,134,151,50,7 Error Correction Codewords (show how these were calculated (msg_coeff=182%2C230%2C247%2C119%2C50%2C7%2C11148 116 177 212 76 133 75 242 238 76 195 230 189 10 108 241

	00000110 (codeword #43) 10000110 (codeword #44) 10010111 (codeword #45) 00110010 (codeword #46) 00000111	
Block 2	(codeword #47) 01000110 (codeword #48) 11110111 (codeword #49) 01110110 (codeword #50) 01010110 (codeword #51) 11000010 (codeword #52) 00000110 (codeword #53) 10010111 (codeword #54) 00110010 (codeword #55) 11100000 (codeword #56) 11101100 (codeword #57) 00010001 (codeword #58)	Data Codewords from the left, as Integers: 70,247,118,86,194,6,151,50,16,236,17,236,17,236,17,236 Error Correction Codewords (show how these were calculated (msg_coeff=70%2C247%2C118%2C86%2C194%2C6%2C151 235 159 5 173 24 147 59 33 106 40 255 172 82 2 131 32 178 2:

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11	Col 12	Col 13	Col 14	Col 15
Block 1	67	85	70	134	87	38	85	194	119	50	6	18	6	103	38
Block 2	246	246	66	7	118	134	242	7	38	86	22	198	199	146	6
Block 3	182	230	247	119	50	7	118	134	87	38	82	6	134	151	50
Block 4	70	247	118	86	194	6	151	50	16	236	17	236	17	236	17



As described above, take the first data codeword from the first block, followed by the first data codeword from the second block, followed by the first data codeword from the third block, followed by the first data codeword from the fourth block.

Or, as shown in the table above, take the data codewords from column 1, starting with block 1 and ending with block 4. The numbers from column 1 are 67, 246, 182, and 70.

Interleaved data so far:
67, 246, 182, 70

After that, put the numbers from column 2, starting with block 1 and ending with block 4.

Interleaved data so far:
67, 246, 182, 70, 85, 246, 230, 247

Do the same with column 3.

Interleaved data so far:
67, 246, 182, 70, 85, 246, 230, 247, 70, 66, 247, 118

Repeat the process, going column by column. Here is the result after adding column 15.

Interleaved data after adding column 15:
67, 246, 182, 70, 85, 246, 230, 247, 70, 66, 247, 118, 134, 7, 119, 86, 87, 118, 50, 194, 38, 134, 7, 6, 85, 242, 118, 151, 194, 7, 134, 50, 119, 38, 87, 16, 50, 86, 38, 236, 6, 22, 82, 17, 18, 198, 6, 236, 6, 199, 134, 17, 103, 146, 151, 236, 38, 6, 50, 17

Column 16 only has two numbers in it, as you can see in the table above. Simply put these two numbers at the end of the interleaved data like so:

Interleaved data codewords:
67, 246, 182, 70, 85, 246, 230, 247, 70, 66, 247, 118, 134, 7, 119, 86, 87, 118, 50, 194, 38, 134, 7, 6, 85, 242, 118, 151, 194, 7, 134, 50, 119, 38, 87, 16, 50, 86, 38, 236, 6, 22, 82, 17, 18, 198, 6, 236, 6, 199, 134, 17, 103, 146, 151, 236, 38, 6, 50, 17, 7, 236

Interleave the Error Correction Codewords

Now that the data codewords have been interleaved, the error correction codewords should be interleaved. This process is illustrated with the table and description below.

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11	Col 12	Col 13	Col 14	Col 15
Block 1	213	199	11	45	115	247	241	223	229	248	154	117	154	111	86
Block 2	87	204	96	60	202	182	124	157	200	134	27	129	209	17	16
Block 3	148	116	177	212	76	133	75	242	238	76	195	230	189	10	10
Block 4	235	159	5	173	24	147	59	33	106	40	255	172	82	2	13



As described above, take the first error correction codeword from the first block, followed by the first error correction codeword from the second block, followed by the first error correction codeword from the third block, followed by the first error correction codeword from the fourth block. Or, as shown in the table above, take the error correction codewords from column 1, starting with block 1 and ending with block 4. The numbers from column 1 are 213, 87, 148, and 235.

Interleaved error correction codewords so far:
213, 87, 148, 235

After that, put the numbers from column 2, starting with block 1 and ending with block 4.

Interleaved error correction codewords so far:
213, 87, 148, 235, 199, 204, 116, 159

Do the same with column 3.

Interleaved error correction codewords so far:
213, 87, 148, 235, 199, 204, 116, 159, 11, 96, 177, 5

Repeat the process, going column by column. Here is the final result.

Interleaved error correction codewords:
213, 87, 148, 235, 199, 204, 116, 159, 11, 96, 177, 5, 45, 60, 212, 173, 115, 202, 76, 24, 247, 182, 133, 147, 241, 124, 75, 59, 223, 157, 242, 33, 229, 200, 238, 106, 248, 134, 76, 40, 154, 27, 195, 255, 117, 129, 230, 172, 154, 209, 189, 82, 111, 17, 10, 2, 86, 163, 108, 131, 161, 163, 240, 32, 111, 120, 192, 178, 39, 133, 141, 236

Put Interleaved Error Correction Codewords After Interleaved Data Codewords

The final message consists of the interleaved data codewords followed by the interleaved error correction codewords.

Final message:

67, 246, 182, 70, 85, 246, 230, 247, 70, 66, 247, 118, 134, 7, 119, 86, 87, 118, 50, 194, 38, 134, 7, 6, 85, 242, 118, 151, 194, 7, 134, 50, 119, 38, 87, 16, 50, 86, 38, 236, 6, 22, 82, 17, 18, 198, 6, 236, 6, 199, 134, 17, 103, 146, 151, 236, 38, 6, 50, 17, 7, 236, 213, 87, 148, 235, 199, 204, 116, 159, 11, 96, 177, 5, 45, 60, 212, 173, 115, 202, 76, 24, 247, 182, 133, 147, 241, 124, 75, 59, 223, 157, 242, 33, 229, 200, 238, 106, 248, 134, 76, 40, 154, 27, 195, 255, 117, 129, 230, 172, 154, 209, 189, 82, 111, 17, 10, 2, 86, 163, 108, 131, 161, 163, 240, 32, 111, 120, 192, 178, 39, 133, 141, 236

Step 3: Convert to Binary

The final message is converted to 8-bit binary. In our example, the first four codewords are 67, 246, 182, and 70. Converted to binary, these are:

67 = 01000011

246 = 11110110

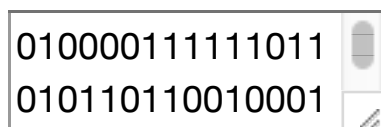
182 = 10110110

70 = 01000110

The 8-bit binary numbers are put together in an unbroken string. Using the first four codewords from above, the first 32 bits of the final message are:

01000011111101101011011001000110

For completeness, the entire final message in binary is in the text box below:



010000111111011
010110110010001

Step 4: Add Remainder Bits if Necessary

For some QR versions, the final binary message is not long enough to fill the required number of bits. In this case, it is necessary to add a certain number of 0s to the end of the final message to make it have the correct length. These extra 0s are called **remainder bits**. A version 5 QR code, like the one in this example, must have 7 remainder bits added to the end.

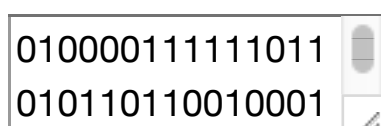
The final 8 bits from the string in the text box above are:

11101100

With the 7 remainder bits added to the end, the final bits of the string are:

111011000000000

For completeness, the entire final message in binary, with the 7 remainder bits added, is in the text box below:



010000111111011
010110110010001

See below for a table that lists the required number of remainder bits for each QR version.

Now that the final binary string has been determined, the next step is to place the data bits and function patterns in the QR code matrix. This process is explained in the module placement in matrix (module-placement-matrix) section.

List of Versions and Required Remainder Bits

The following table lists the 40 QR versions and the number of remainder bits that must be added to the end of the final message string. Note that the remainder bits specified for each version are required no matter which error correction level is in use. Also note that some versions, such as versions 7 through 13, do not require any remainder bits to be added.

QR Version	Required Remainder Bits
1	0
2	7
3	7
4	7
5	7
6	7
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	3
15	3
16	3
17	3
18	3
19	3
20	3
21	4
22	4

23	4
24	4
25	4
26	4
27	4
28	3
29	3
30	3
31	3
32	3
33	3
34	3
35	0
36	0
37	0
38	0
39	0
40	0

Next Step

As mentioned above, the next step is the module placement in matrix (module-placement-matrix). This section explains how to place the data bits as well as the function patterns that all QR codes require.



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