Final Lab : Bicubic Resize Engine(Bicubic)

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Outline

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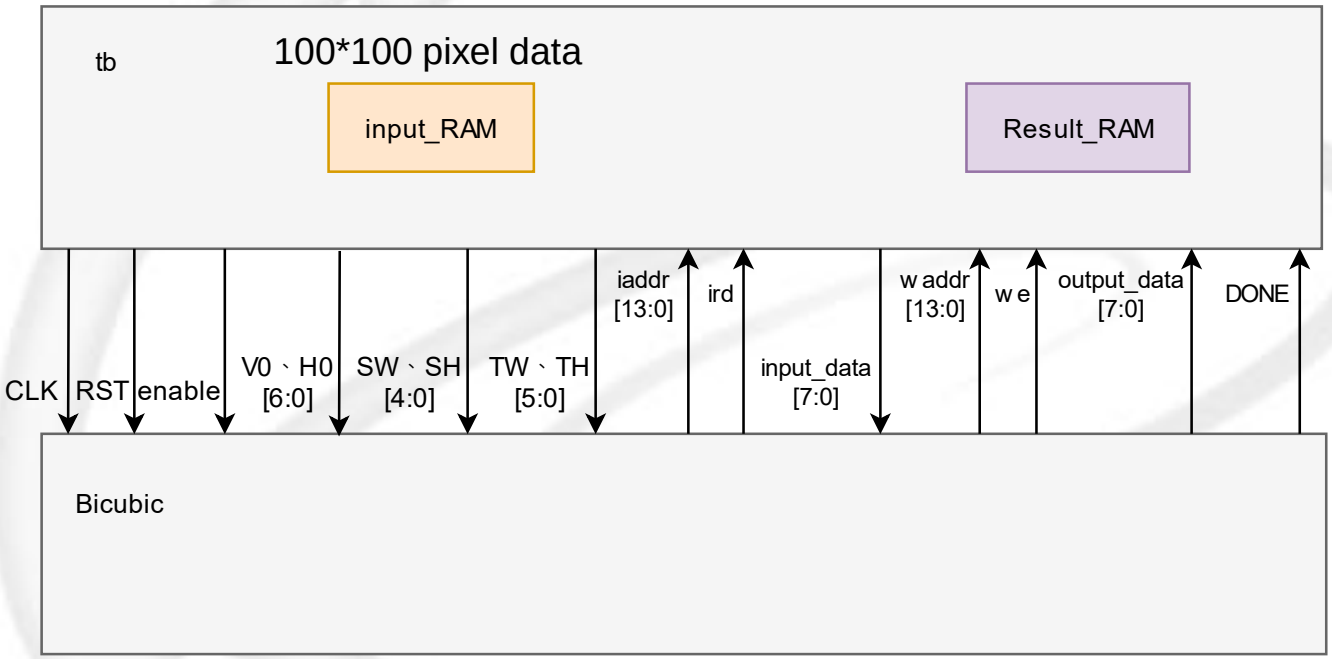
Introduce to Interpolation

- Interpolation is a method to estimate value between known data points.
- There three common interpolation:
  - Linear interpolation (1-dimension)
  - Cubic interpolation (1-dimension)
  - Bicubic interpolation (2-dimension)
- Bicubic interpolation is commonly used in tasks such as image resizing to achieve high-quality results.
- This circuit can enlarge selected 2-dimensional matrix data to the desired size.

Hardware description

Block Diagram



Hardware description

I/O Information

Signal	I/O	length	Desc.
CLK	I	1	positive-edged triggered
RST	I	1	asynchronous positive-edged triggered
enable	I	1	enable signal to start processing
ird	O	1	Active high read enable signal for input_RAM
iaddr	O	14	Address for input_RAM
input_data	I	8	Read 8bits unsigned data from input_RAM
we	O	1	Active high write enable signal for Result_RAM
waddr	O	14	Address for Result_RAM
output_data	O	8	Write 8bits unsigned data to Result_RAM
DONE	O	1	Finish signal

Hardware description

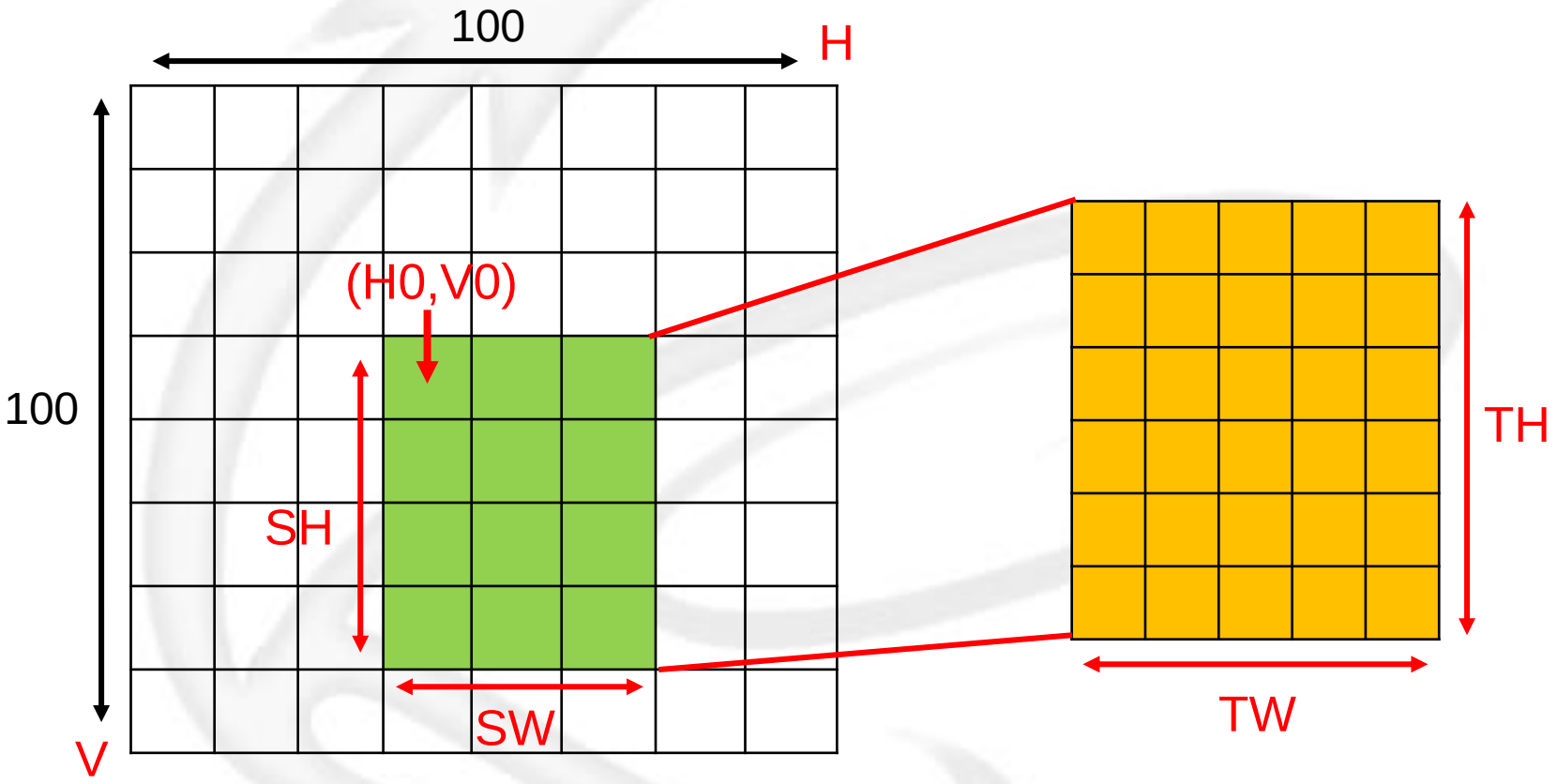
I/O Information

Signal	I/O	length	Desc.
H0	I	7	The horizontal coordinate value at the top-left corner of the region to be processed
V0	I	7	The vertical coordinate at the top-left corner of the region to be processed
SW	I	5	The horizontal width of the region to be processed
SH	I	5	The vertical height of the region to be processed
TW	I	6	The horizontal width of the region after being enlarged
TH	I	6	The vertical height of the region after being enlarged

The value of the signals at this page will be transimitted from start to done.

Hardware description

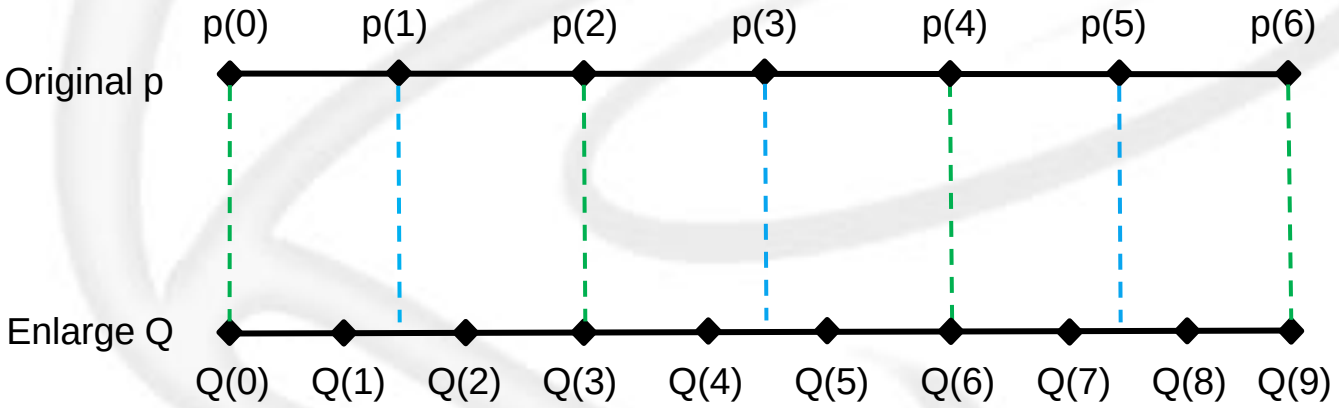
- Determine the interpolation point



Implementation

Determine the interpolation point

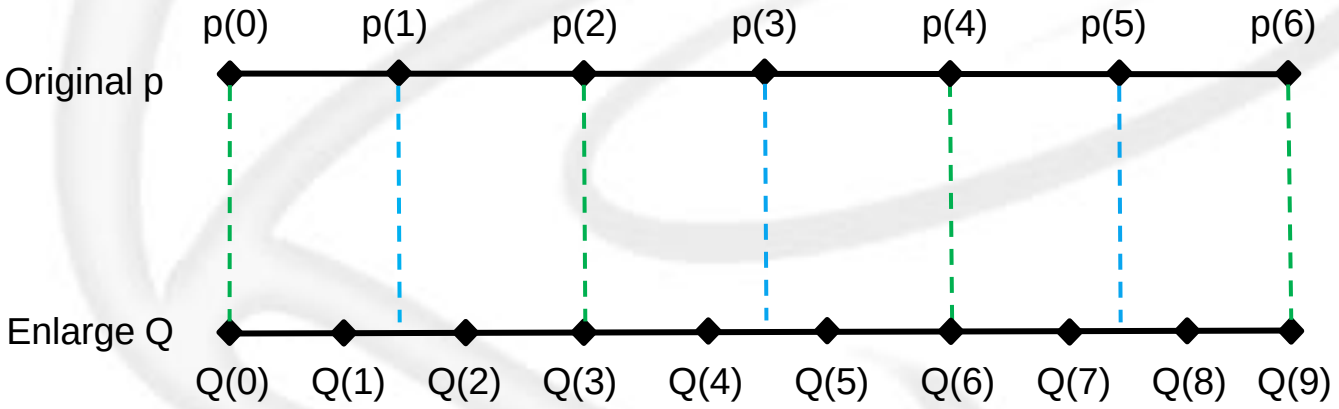
- Considering the case of enlarging a 1x7 image p to 1x10 image Q in 1D space. The goal is to determine all the values of Q(x).
- Compressing the Q image to the same length as the p image, where the two images overlap at both first point and end point, so Q(0)=p(0) and Q(9)=p(6).
- Some intermediate points of Q and P may overlap, so their value can be obtained directly from p, in this case, Q(3)=p(2),Q(6)=p(4).



Implementation

Determine the interpolation point

- For those remaining non-overlapping points, their value cannot be directly obtained. It is necessary to find the closest points from P image and then use interpolation methods to find out the value of Q(x).
- In this case, the interpolation point of Q(1) are p(0) and p(1), and for Q(2) are p(1) and p(2), and for Q(4) are p(2) and p(3), and so on.

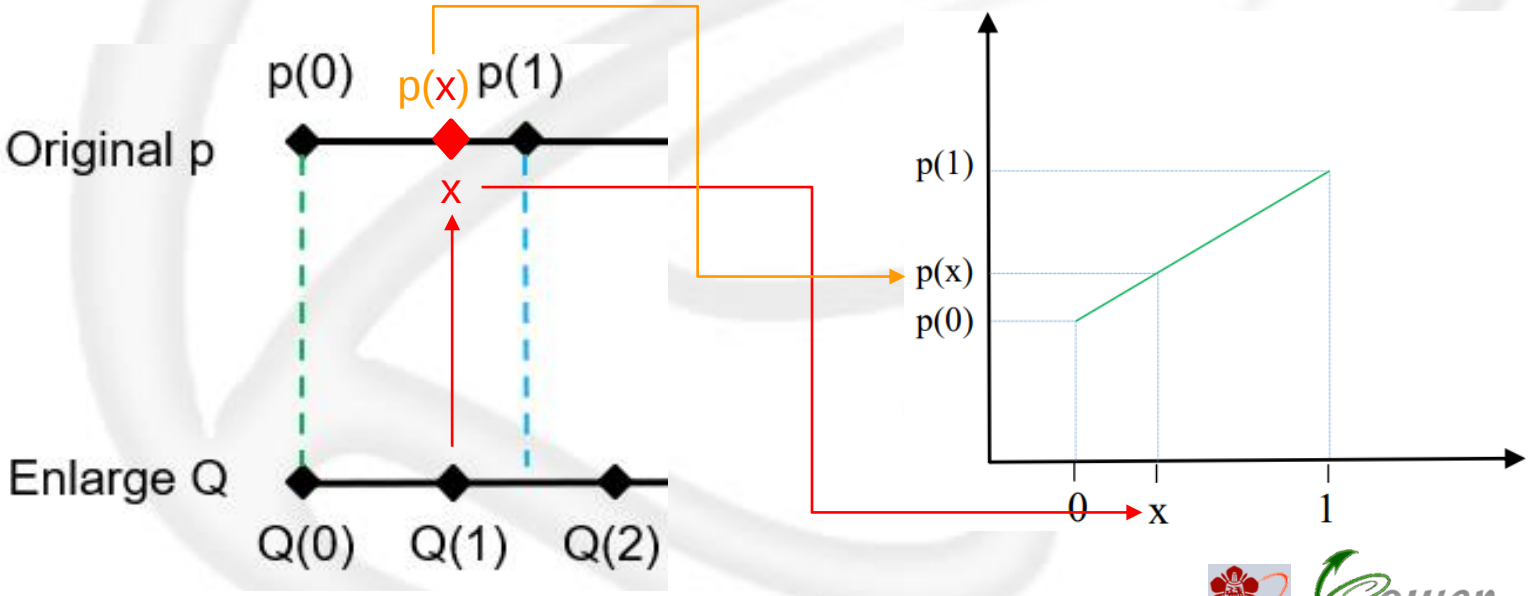


Implementation

Linear interpolation

- Given the values of points p(0) and p(1), to find the value of point p(x), where 0≤x≤1, the linear interpolation formula is :

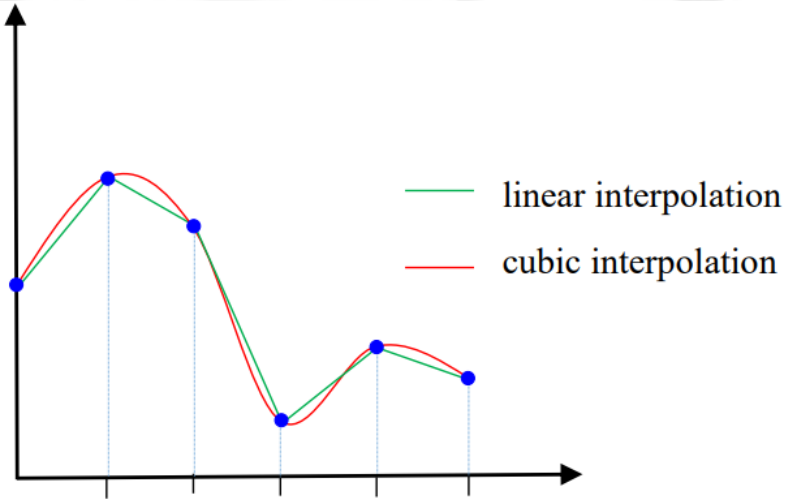
$$p(x) = p(0) + x \cdot \frac{p(1) - p(0)}{1 - 0} = p(0) + x \cdot (p(1) - p(0))$$



Implementation

Cubic interpolation

- However, linear interpolation only considers between two points, it may produces non-smooth curves like green line below.
- This issue can be improved by using cubic interpolation like red line below.



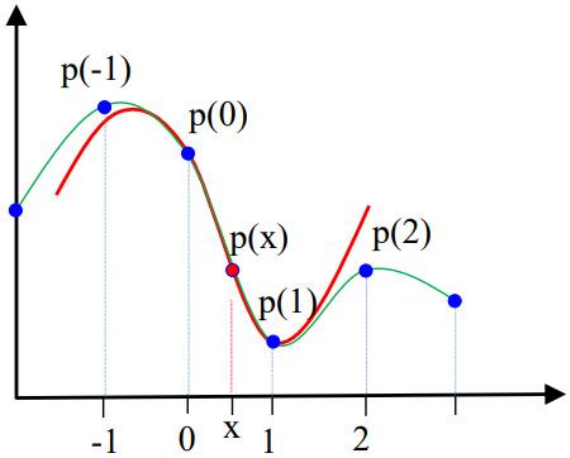
Implementation

Cubic interpolation

- Given the value of points p(-1), p(0), p(1) and p(2) to find the interpolated value of point p(x), where 0≤x≤1.
- Assuming the curve between points p(0) and p(1) is a 3rd order polynomial : $p(x) = ax^3 + bx^2 + cx + d$, where 0≤x≤1.
  - a = $\frac{-1}{2}p(-1) + \frac{3}{2}p(0) - \frac{3}{2}p(1) + \frac{1}{2}p(2)$
  - b = $p(-1) - \frac{5}{2}p(0) + 2p(1) - \frac{1}{2}p(2)$
  - c = $\frac{-1}{2}p(-1) + \frac{1}{2}p(1)$
  - d = $p(0)$

  See Appendix-1

- Substituting the value of a,b,c,d back to the 3rd order polynomial and you can get p(x).

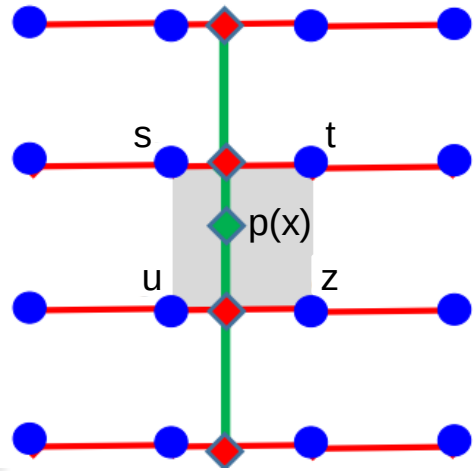


Hint: the precision of x is important !!

Implementation

Bicubic interpolation

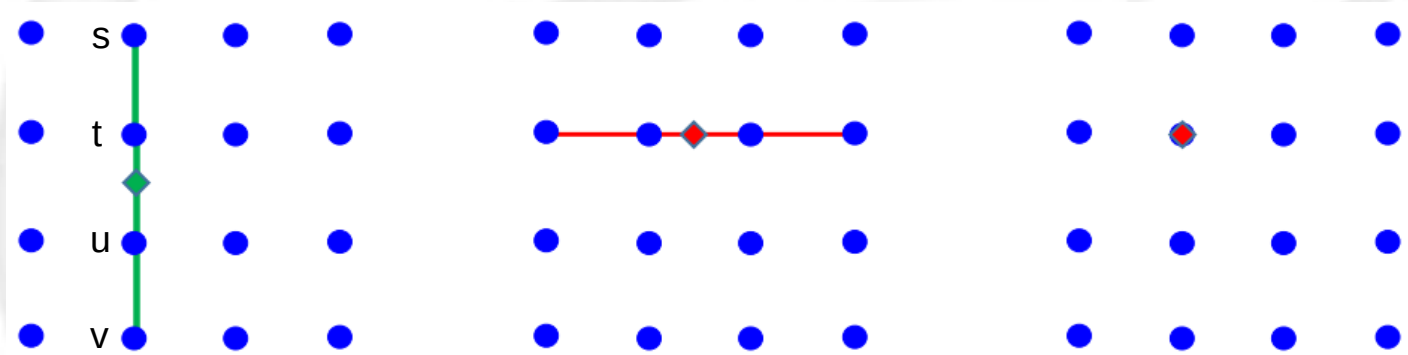
- In one-dimension cubic interpolation, the interpolated value p(x) is calculated using 4 points p(-1),p(0),p(1) and p(2).
- In two-dimension Bicubic interpolation, the interpolated value p(x) is calculated using 16 points. Taking the example in the figure below, to obtain the interpolated value p(x) between points s,t,u and v, you need to calculate one-dimension cubic interpolation results for each of the 4 rows(red lines), and then use these 4 results to calculate one-dimension cubic interpolation for the column(green lines), and this is the answer.



Implementation

Bicubic interpolation

- If the vertical or horizontal coordinates match the original image, you can use the original image values directly.
- Taking the bottom-left image as an example, you only need to use the four points s,t,u and v and do one cubic interpolation to obtain the interpolated value of green point.



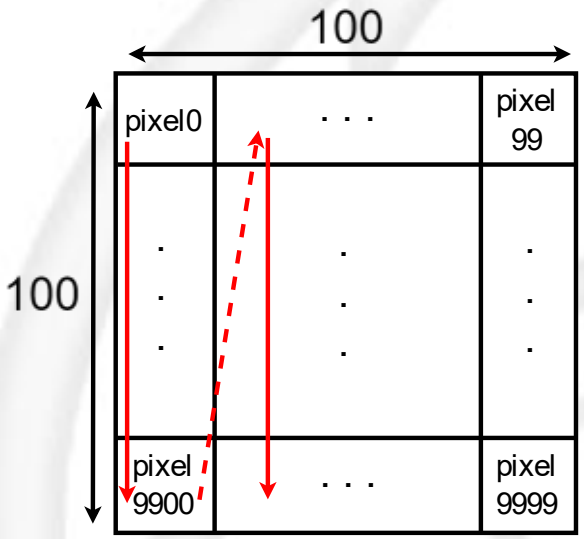
Implementation

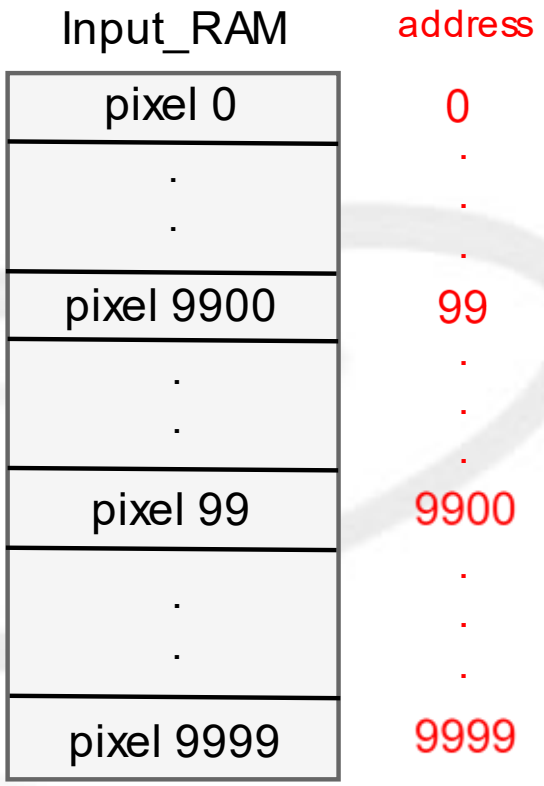
Things to note

- The specified enlargement area will not at the boundary, so there's no need to handle edge issues.
- In cubic interpolation, round each computation result to the nearest integer(including 4 horizontal and 1 vertical interpolation in page 13)
- The result of cubic interpolation may exceed the 8bits value range. If the interpolation result is greater than 255, set it to 255；if it is less than 0, set it to 0(including 4 horizontal and 1 vertical interpolation in page 13)
- You can use python or other software to help you debug.

Implementation

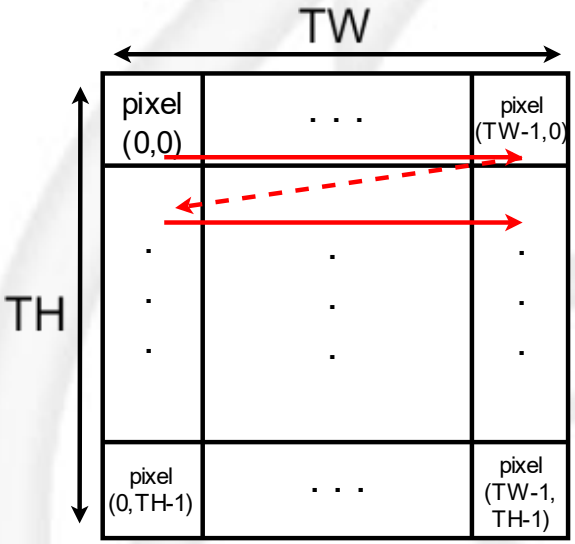
- Input Memory mapping
  - Column major

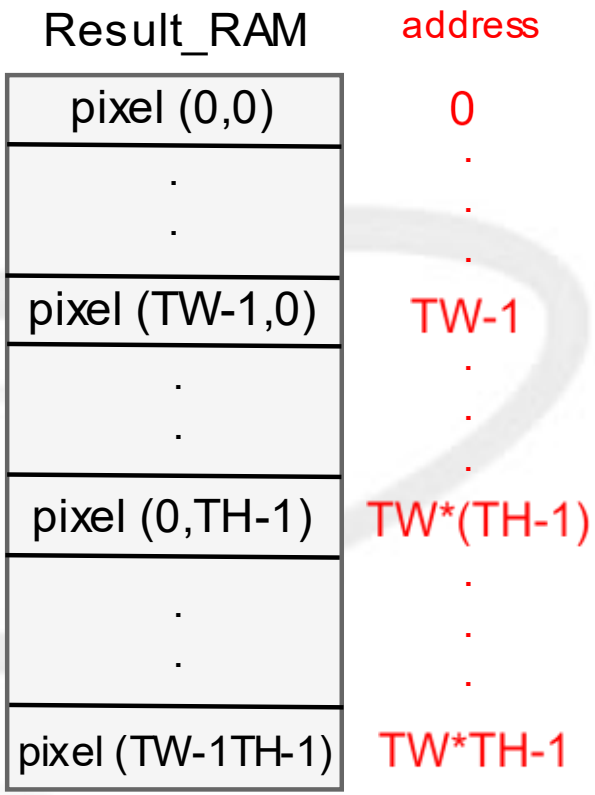




Implementation

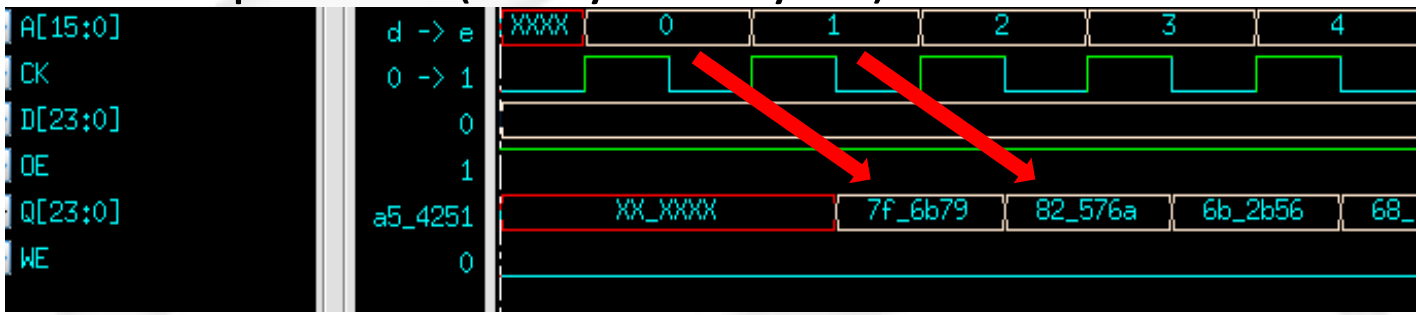
- Output Memory mapping
  - Row major





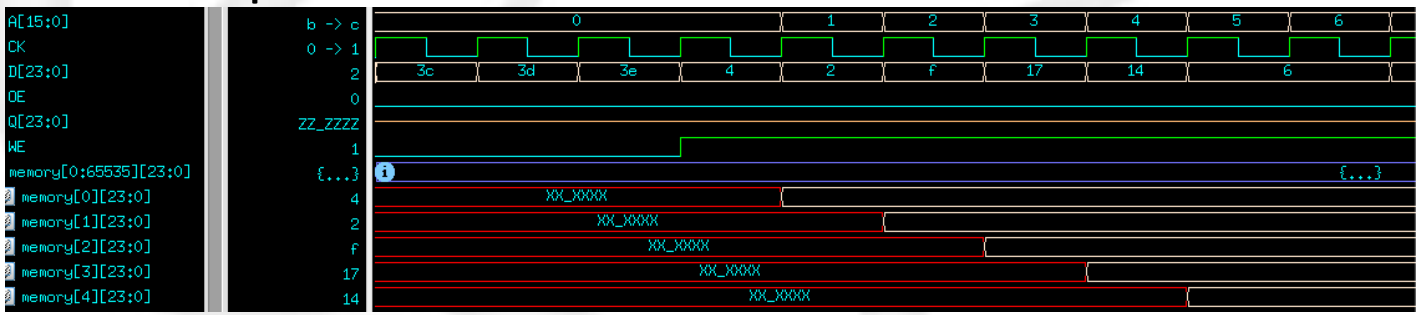
Implementation

- The timing information for Read/Write SRAM
  - Read operation(delay one cycle)



✓ The memory will output values on the negative edge, and you need to capture data on the positive edge

  - Write operation



tb

- You can only modify those red boxes in tb

```
1   `timescale 1ns/10ps
2   `define CYCLE_TIME      150.0
3   `define MAX_CYCLE_PER_PATTERN  150000
4   `define PLOT_IMG
5   // `define USECOLOR
```

Modify your cycle time and max cycle

// `define USECOLOR

```
---- resize  19 x  19
 3f 48 4d 4c 4e 4f 4f 51 49 3a 35 3d 4f 4f 4d 4c 4b 4b 4a
 4a 2c 1d 27 43 52 4f 51 48 39 34 3c 4e 4e 4d 4d 4c 4b 4a
 4c 25 16 28 45 52 4f 51 48 38 33 3c 4e 4e 4d 4d 4c 4b 4a
 4a 3e 3d 49 4a 4b 4e 50 48 38 33 3c 4d 4d 4c 4c 4b 4b 4a
 49 4b 3a 1c 0e 20 4c 50 45 36 31 39 4a 4a 49 48 48 48 47
 49 4e 3b 15 1d 27 31 39 35 29 26 2c 38 38 37 36 36 36 35
 48 4b 44 3b 6c 58 06 16 21 19 18 1c 22 21 20 20 20 20 1f
 49 4b 4a 47 3e 2b 17>36 3e 2d>2a 31 3e 3f 3e 3d 3d 3d 3c
 3d 45 4b 4a 2f>1f 24 35>3e 39 34 3d 4f 50>50 4e 4e 4e 4d
 2a 39 49 49 4c 40 26 17 1e 35 32 39 4c 4d 4c 4b 4b 4b 4a
 34 3e 4a 47 4b 45 38 3f 34 1a 28 3b 4b 4c 4b 4b 4b 4b 4a
 6b 3a 2f 47 49 47 44 49 40 2b 2a 36 4b 4c 4b 4b 4b 4b 4a
 bb 38 0c 46 48 48 48 31 3a 5c 36 2e 4b 4c 4a 4a 4b 4b 4a
 bb 89 51 2e 3e 49 47 43 36 27 32 41 4d 4c 4a 4a 4a 4a 4a
 91 b5 8d 34 3b 45 46 4b 3c 1d 2b 35 38 47 4d 4a 4a 4a 4a
 51 a5 a9 5e 42 3c 46 46 48 46 28 13 13 39 4e 4a 4a 4a 4a
 27 74 a7 a4 46 24 4a 49 47 48 3f 2d 14 0d 25 4f 4e 4a 49
 16 43>89 c5 7b 3d 2c 3f 4a 46>4b 41 28 0e>14 35 47 4d 49
 1c 21 57 b0 cb 85 06 2c 4b 46 46 46 44 3b 21 06 34 4f 49
---- error count          8
```

The value on the right side of the “>” is error, so 1f is error.

`define USECOLOR (if your environment can display color)

```
---- resize  19 x  19
    0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
 0 3f 48 4d 4c 4e 4f 4f 51 49 3a 35 3d 4f 4f 4d 4c 4b 4b 4a
 1 4a 2c 1d 27 43 52 4f 51 48 39 34 3c 4e 4e 4d 4d 4c 4b 4a
 2 4c 25 16 28 45 52 4f 51 48 38 33 3c 4e 4e 4d 4d 4c 4b 4a
 3 4a 3e 3d 49 4a 4b 4e 50 48 38 33 3c 4d 4d 4c 4c 4b 4b 4a
 4 49 4b 3a 1c 0e 20 4c 50 45 36 31 39 4a 4a 49 48 48 48 47
 5 49 4e 3b 15 1d 27 31 39 35 29 26 2c 38 38 37 36 36 36 35
 6 48 4b 44 3b 6c 58 06 16 21 19 18 1c 22 21 20 20 20 20 1f
 7 49 4b 4a 47 3e 2b 17 36 3e 2d 2a 31 3e 3f 3e 3d 3d 3d 3c
 8 3d 45 4b 4a 2f 1f 24 35 3e 39 34 3d 4f 50 50 4e 4e 4e 4d
 9 2a 39 49 49 4c 40 26 17 1e 35 32 39 4c 4d 4c 4b 4b 4b 4a
10 34 3e 4a 47 4b 45 38 3f 34 1a 28 3b 4b 4c 4b 4b 4b 4b 4a
11 6b 3a 2f 47 49 47 44 49 40 2b 2a 36 4b 4c 4b 4b 4b 4b 4a
12 bb 38 0c 46 48 48 48 31 3a 5c 36 2e 4b 4c 4a 4a 4b 4b 4a
13 bb 89 51 2e 3e 49 47 43 36 27 32 41 4d 4c 4a 4a 4a 4a 4a
14 91 b5 8d 34 3b 45 46 4b 3c 1d 2b 35 38 47 4d 4a 4a 4a 4a
15 51 a5 a9 5e 42 3c 46 46 48 46 28 13 13 39 4e 4a 4a 4a 4a
16 27 74 a7 a4 46 24 4a 49 47 48 3f 2d 14 0d 25 4f 4e 4a 49
17 16 43 89 c5 7b 3d 2c 3f 4a 46 4b 41 28 0e 14 35 47 4d 49
18 1c 21 57 b0 cb 85 06 2c 4b 46 46 46 44 3b 21 06 34 4f 49
---- error count          8
```

The red values mean error.

sdc file

- You can only modify those red box in Bicubic.sdc

```
1   # operating conditions and boundary conditions #
2
3   set cycle 150.0
4   create_clock -name CLK  -period $cycle   [get_ports  CLK]
5
6
7   #Don't touch the basic env setting as below
8   set_input_delay  5.0   -clock CLK [remove_from_collection [all_inputs] [get_ports CLK]]
9   set_output_delay 5.0    -clock CLK [all_outputs]
10
```

Do not set more than 150ns

- Ensure the clock period in the sdc file matches the value defined in your tb.

Criteria

- Three test patterns
  - Appendix-2,3,4 has target values

```
run -all
**********************************
** Simulation Start          **
**********************************
== PATTERN pattern1
---- orgin ( 10 ,  68), size  13 x  13
 3f 4c 4c 4f 4f 4f 3a 36 4f 4e 4c 4b 4a
 4c 0f 1c 4e 4f 4f 38 35 4e 4d 4d 4b 4a
 4a 3a 49 4a 4e 4e 38 35 4d 4c 4c 4b 4a
 49 4a 0c 02 45 46 32 2f 45 44 43 43 42
 48 4a 3b 76 06 22 19 19 22 20 20 20 1f
 46 49 49 1c 22 4b 36 34 4c 4c 4b 4b 4a
 2a 46 49 4a 26 16 35 32 4c 4c 4b 4b 4a
 46 44 46 49 40 50 16 32 4b 4b 4b 4b 4a
 bb 06 46 46 48 2c 5c 27 4b 4a 4a 4b 4a
 ab 99 2a 46 46 48 13 3e 48 4a 4a 4a 4a
 51 bc 5e 3c 46 46 46 1a 13 4a 4a 4a 4a
 1a 7c bd 27 45 46 46 46 1c 01 4a 4a 49
 1c 30 b0 bc 06 46 46 46 44 32 06 4a 49
---- resize  19 x  19
 3f 48 4d 4c 4e 4f 4f 51 49 3a 35 3d 4f 4f 4d 4c 4b 4b 4a
 4a 2c 1d 27 43 52 4f 51 48 39 34 3c 4e 4e 4d 4d 4c 4b 4a
 4c 25 16 28 45 52 4f 51 48 38 33 3c 4e 4e 4d 4d 4c 4b 4a
 4a 3e 3d 49 4a 4b 4e 50 48 38 33 3c 4d 4d 4c 4c 4b 4b 4a
 49 4b 3a 1c 0e 20 4c 50 45 36 31 39 4a 4a 49 48 48 48 47
 49 4e 3b 15 1d 27 31 39 35 29 26 2c 38 38 37 36 36 36 35
 48 4b 44 3b 6c 58 06 16 21 19 18 1c 22 21 20 20 20 20 1f
 49 4b 4a 47 3e 2b 17>36 3e 2d>2a 31 3e 3f 3e 3d 3d 3d 3c
 3d 45 4b 4a 2f>1f 24 35>3e 39 34 3d 4f 50>50 4e 4e 4e 4d
 2a 39 49 49 4c 40 26 17 1e 35 32 39 4c 4d 4c 4b 4b 4b 4a
 34 3e 4a 47 4b 45 38 3f 34 1a 28 3b 4b 4c 4b 4b 4b 4b 4a
 6b 3a 2f 47 49 47 44 49 40 2b 2a 36 4b 4c 4b 4b 4b 4b 4a
 bb 38 0c 46 48 48 48 31 3a 5c 36 2e 4b 4c 4a 4a 4b 4b 4a
 bb 89 51 2e 3e 49 47 43 36 27 32 41 4d 4c 4a 4a 4a 4a 4a
 91 b5 8d 34 3b 45 46 4b 3c 1d 2b 35 38 47 4d 4a 4a 4a 4a
 51 a5 a9 5e 42 3c 46 46 48 46 28 13 13 39 4e 4a 4a 4a 4a
 27 74 a7 a4 46 24 4a 49 47 48 3f 2d 14 0d 25 4f 4e 4a 49
 16 43>89 c5 7b 3d 2c 3f 4a 46>4b 41 28 0e>14 35 47 4d 49
 1c 21 57 b0 cb 85 06 2c 4b 46 46 46 44 3b 21 06 34 4f 49
---- error count          8
```

```
 16 43>89 c5 7b 3d 2c 3f 4a 46>4b 41 28 0e>14 35 47 4d 49
 1c 21 57 b0 cb 85 06 2c 4b 46 46 46 44 3b 21 06 34 4f 49
---- error count          8
== PATTERN pattern2
---- orgin ( 81 ,  18), size  17 x  15
 3a 39 38 1f 8d ca 8f 6a 6c 6e 6e 71 75 77 78 7f 80
 27 3a 39 38 16 a4 bc 7c 69 6b 6d 6e 72 76 7c 7b 7a
 5c 2d 3a 3a 39 06 c8 b6 6e 69 6b 6d 72 7a 78 76 78
 17 55 2b 3b 3a 39 22 c7 ac 68 69 6e 79 75 72 73 75
 3f 06 71 3a 3b 3a 34 57 c7 8f 6b 77 72 6e 6e 71 73
 40 3f 57 12 3d 3c 3b 26 95 bc 7d 6e 6a 6b 6d 70 7b
 41 40 06 44 16 3d 3d 3b 06 d1 af 66 67 69 6b 78 7e
 41 41 0e 2e 60 2f 3e 3d 38 58 c6 82 66 67 6e 74 71
 41 41 0e 41 11 30 3f 3e 3d 1c c3 b1 67 66 6b 6b 6c
 25 25 06 25 25 53 01 3f 3e 3d 24 c4 8e 64 67 68 6a
 2f 2e 0c 2e 2e 14 65 3c 3f 3e 2c a9 b1 65 64 66 68
 43 43 10 43 43 43 06 05 41 40 3f 22 c2 89 63 65 6b
 43 43 11 43 43 43 3c 5e 3a 41 40 2c ac b7 62 68 78
 43 43 11 44 45 44 43 06 01 41 41 3f 2a c1 85 75 72
 43 43 11 44 45 45 45 3b 5d 3c 41 40 1c c0 af 6b 64
---- resize  22 x  28
 3a 3a 3a 2f 21 79 bb be 8a 6d 69 6d 6e 6e 70 73 76 77 77 7b 80 80
 2d 37 3c 34 27 3c 95 c6 a3 75 69 6a 6c 6d 6e 71 74 76 79 7c 7e 7d
 28 35 3b 3a 37 11 63 b5 ba 86 6e 68 6b 6d 6d 70 73 76 7b 7c 7b 7a
 49 34 34 3c 3a 24 2c 72 d3 a6 78 64 6a 6c 6c 6f 72 79 7a 7a 78 79
 5a 37 31 3a 3a 3d 0c 38 c8 bf>8a 69 69 6b 6c 6f 73 7a 79 77 76 78
 31 48 3b 2d 3b 3d 25 2c 6b c4 af 7e 63 69 6c 71 77 78 76 74 74 76
 17 47 41 30 3b 3a 3d 2c 25 b0 c3 97 66 68 6c 73 79 74 72 72 73 75
 2e>1d 3f 58 3d 3a 3d 32 2a 75 b6 b1 78 69 70 76 74 70 70 70 71 73
 41 0b 41 6b 34 3a 3c 38 36 43 9f bf>8e 6e 72 75 70 6d 6e 6f 71 74
 41 2b 4f 58 1a 39 3f 3b 38 29 82 bb a9 78 70 6f 6c 6c 6d 6e 71 78
 40 42 4a 3e 17 31 3c 3d 3a 23>58 a0 c1 8a 71 69 69 6b 6c 6e 73 7c
 41 44 2a>1f 38 1d 2e 40 3c 36 1d 65 db a8 75 62 68 6a 6a 70 78 7e
 41 45 1b 0e 44 26 2f 3d 3e 40 0b 43 c8 bb 80 63 66 69 6a 71 7a 7d
 41 45 21 0f 34 52 42 33 3f 3e 2a 40 83 c1 92 6c 65 67 6c 72 76 74
 42 46 25 13 33 52 3e 30 41 3d 3c 38>51 c5>a7>78 62 67 6c 70 72 6f
 43 47 24 18>40 23 24 35 44 3e 3f 2c 32 c5 bf 89 60 66 6b 6c 6d 6d
 3a 3d 1f 15 3b 15 28 39 2d 3c 41 2e 2a 91 bb 9e 6a 66 69 6a 6a 6b
 28 2b 15 0c 29 20 43 3c 04 38 41 3c 36 34 a0 b6 7e 65 66 69 68 6a
 25 27 13 0c 26 27 3a>38 1f 3d 40 41 3a 15>93 c1>90 64 63 67 67 69
 2d 2e 19 11 2d 2e 1c 2d 60 43 3d 40 3b 24 8a be a2 65 62 65 66 68
 37 39 1e 15 37 38 26 2c 49 28 35 42 3d 31 5f 9d b4 72 64 64 66 68
 42 45 24 19 43 43 44 30 08 02 2c 45 40 3e 26 6b c3 87 69 61 66 6a
 44 48 26 19 45 45 49 37 13 23 39 43 41 42 1a 5f c7 a0 6d 5e 68 71
 43 46 25 19 44 44 43 3f 3b 5a 49 3c 41 41 27 61 bb b7 74 5d 6b 78
 43 46 25 19 44 45 44 44 42 3d>27 27 43 41 33 4a>84 be 84 69 71 77
 43 46 25 1a 45 46 45 46 3f 0d 00 17 44 41 40 2f 42 be 98 79 74 72
 43 46 25 1a 45 46 45 46 41 1c 26 36 42 41 44 27 2f c3 ae 85 6e 6b
 43 46 25 1a 45 46 45 45 44 3a 53 54 3b 41 43 29 31 bc bd 8e 65 64
---- error count         14
```

The value on the right side of the “>” is error, so 14 is error.

```
== PATTERN pattern3
---- orgin ( 45 ,  45), size  16 x  29
 4b 4d 4f 50 48 27 51 51 50 4e 4b 4a b9 be c0 c4
 13 39 52 53 4d 2c 54 54 52 50 4e 48 b5 ba be c2
 ae ac 1f 39 4f 2f 58 57 55 54 51 45 b3 b7 bb bf
 ac a9 a7 a6 25 13 5a 5a 57 56 53 42 b0 b4 b9 bd
 aa a8 a6 a4 a3 8c 15 4c 4b 48 45 4f af b2 b7 bb
 a9 a7 a4 a3 a0 a0 93 0c 3e 3c 3a 5a ad b2 b5 ba
 a9 a6 a4 a1 a0 a0 9f 52 57 5a 57 3e ac b1 b4 b9
 1c 5c a4 a1 a0 9f 9e 9f 2b 5b 58 3e ac b1 b5 b9
 55 45 45 a2 a1 a0 9f a0 04 5a 58 3f ad b1 b5 b9
 54 56 30 a4 a2 a1 a1 a2 10 59 57 40 ae b1 b6 ba
 52 54 38 a5 a4 a3 a3 a3 04 57 55 42 af b3 b7 bc
 4f 50 17 a7 a7 a6 a6 a6 0f 54 52 44 b2 b5 ba be
 06 49 ad ab aa a9 a9 a9 3b 51 4f 46 b5 b8 bc c1
 b4 b1 b0 ae ad ac ad 1c 4f 4e 4c 4a b8 bb bf c4
 b8 b5 b3 b2 b1 b0 43 44 4c 4b 48 4e bc bf c3 c7
 bc ba b8 b5 a9 4e 32 3d 3b 3a 38 5d c0 c4 c7 cb
 c1 8b 63 32 01 0c 20 1f 1e 1c 1a 45 59 5c 5f 5f
 32 3b 3d 3e 36 17 3f 3f 3d 3b 3a 37 35 32 2f 29
 34 35 37 38 31 12 3a 39 38 36 35 32 30 2d 2c 26
 30 32 32 32 2b 0c 34 34 32 31 2f 2e 2c 2a 27 22
 2d 2d 2e 30 27 06 2e 2e 2d 2d 2b 2a 29 27 25 20
 2a 2a 2b 2b 22 02 2b 2a 29 29 29 27 25 24 22 1f
 27 27 27 27 1f 01 27 27 25 26 25 22 22 20 20 1c
 26 25 25 25 1c 04 24 24 22 22 20 20 20 20 20 1c
 24 24 24 22 1a 05 22 22 20 20 20 1f 1f 1f 1e 1a
 22 22 22 22 1a 06 20 20 20 20 1f 1f 1f 1f 1f 1a
 1a 1a 17 18 11 0c 18 18 18 17 16 16 16 16 16 11
 06 06 0c 0f 18 25 1f 22 27 2c 30 30 32 34 37 3a
 22 22 22 20 19 06 20 20 1f 20 1f 1a 19 16 16 15
---- resize  26 x  37
 4b 4d 4d 4f 50 50 4d 42 29 34 51 53 51 50 4f 4e 4c 49 43 73 b9 c1 bf c0 c5 c4
 12 20 3c 51 57 54 52 46 2d 38 53 55 53 52 50 4f 4e 4b 42 71 b6 be bc be c4 c2
 68 75 6e 37 2c 3d 4d 4d 4d 33 3c 56 58 56 54 53 52 51 4c 41 6e b4 bb b9 bb c2 c0
 b9 be a2 53 45 57 4a 37 23 36 5b 5c 59 57 56 55 54 4e 3f 6b b2 b9 b7 b9 be be
 ac a9 a9 ac>b2 ab 5d 21 17 2e 54 5b 5a 57 56 55 54 4d 3e 6b b0 b7 b5 b8 bb bd
 aa a9 a8 a7 a6 a5 a0 97 8c 54 14 35 53 4e 4b 4a 47 46 46 73 af b5 b3 b6 b9 bb
 a9 a8 a7 a5 a4 a3 a5 a5 a3 8f 6a 33 1a 38 41 3d 39 3e 4f 7b ae b4 b3 b5 b8 ba
 b1 b0 a9 a4 a3 a2 a0 a0 a1 a7 a1 4f 20 42 4d 48 46 45 48 72 ac b4 b3 b3 b6 ba
 8f 98 9d a4 a5 a1 a0 a0 a0 a2 a0 7c 5d 53 55 5c 5d 53 3a 64 ac b4 b2 b3 b7 b9
 1c 3c 6b 9a a8 a1 a0 a0 9f 9f 9e a7 8d 3a 35 5b 5d 52 3b 65 ac b4 b2 b4 ba b9
 48 45 47 50 74 a2 a5 a1 a0 a0 9f ab 89 1b 1d 5a 5f 52 3c 66 ad b4 b2 b4 bb b9
 58 53 47 30 5c a3 a7 a1 a0 a0 a0 ac 89 1c>1c 5a 5e 52 3c 67 ae b5 b2 b5 bc b9
 53 58 4f 30>5b a4 a9 a3 a2 a2 a2 ad 8b 1f 1f 58>5d 51 3d 68 ae b5 b3 b5 bc bb
 52 55 4d 32 5d a5 aa a4 a3 a3 a3 ae 8a 17 18 57 5b 50 3e 69 af b6 b4 b6 bd bc
 52 56 45 12 46 a7 ae a7 a6 a6 a6 b1 8d 1f 1c 54 58 4e 3f 6c b2 b9 b6 b9 c0 be
 0f 2b 4f 74 93 aa ab a9 a8 a7 a8 b8 9f 3f 31 52 53 4d 40 6e b4 bb b8 ba c1 c0
 4c 60 83 b0 b8 ac ab ab aa b0 b1 88 60 4a 47 50 4f 4b 41 71 b6 bd ba bc c3 c2
 c0 bc>b8 b2 af af>ad af b0 ad 9b 46 19 46 53 4e 4c 4a 44 74 b9 c0 bd bf c6 c5
 b8 b6 b5 b3 b3 b2 b1 b3 b7 87 43 3e 45 4b 4c 4b 49 47 46 78 bc c3 c0 c2 c9 c7
 bb bc bd bc bd bd bf aa 73 4b 34 3a 41 41 40 3f 3b 40 50 86 c6 ce cb cc d3 d2
 c9 b4 9f 90 7e 6a 54 3e 27 20 25 28>2a 28 27 26 22 2a 47 69 88 8d 8d 8f 91 91
 97 81 69 58 43 2c 11 03 07 16 28>29>27 25 24 23 20 26 3a 44 47 48 48 4a 48 47
 2c 33 38 3b 3d 3e 3d 32>1a>25 40 42 40 3e 3d 3c 3b 3b 37 35 33 31 2f 2e 2c 26
 33 35 35 37 39 39 37 2c 15 20 3b 3c 3a 39 38 37 36 36 34 31 30 2e 2d 2c 2b 26
 31>33 33 34 34 34 32 27 10 1b 36 38 36 34 34 33 32 31 30 2e 2d 2c 2a 29 28 23
 2f 2f 30 30 31 31 2f 23 0b 16 31 33 31 30 30 2f 2e 2d 2c 2c 2b 2a 28 27 25 21
 2c 2c 2c 2d 2e 2f 2c 20 07 12 2d 2f 2d 2c 2c 2c 2b>2b 29 29 28 27 26 25 24 20
 2a 2a 2a 2b 2c 2b 28 1c 04 0f 2b 2c 2a 29 29 29 29 27 26 25 24 24 22 22 1f
 28 28 28 28 28 28 25 1a 03 0d 28 2a 28 26 26 27 27 25 23 23 23 22 21 20 1f 1d
 26 26 26 26 26 26 22 18 04 0d 25 27 25 23 23 24 23 22 21 21 21 20 20 20 1f 1c
 25 25 25 25 25 24 20 17 05 0e 23 25 23 21 21 21 20 20 20 20 20 20 1f 1e 1b
 24 24 24 24 24 22 1e 16 06 0e 22 24 22 20 20 20 20 20 1f 1f 1f 1f 1f 1e 1d 1a
 22 22 22 23 23 22 1e 16 07 0e 20 22 20 20 20 20 20 1f 1f 1f 1f 1f 1f 1e 1a
 1e 1e 1e 1b 1b 1c 17 11 09 0e 1a 1b 19 19 19 18 17 17 17 17 17 17 16 16 14 11
 0f 0f 10 10 11 13 13 15 18 1a 1a 1b 1c 1e 1f 20 21 22 22 22 23 23 24 25 25 24
 09 09 0a 0e 10 11 16 1b 21 22 20 21 23 26 28 2b 2e 2f 2e>2f 2f 30 31 32 34 36
 22 22 22 22 22 20 1d 15 07 0e 20 21 20 1f 1f 20 20 1e 1b 19 19 17 16 16 16 15
---- error count         14

**********************************
**  Finish Simulation
**  Error pixels:      36
**  Simulation time:  7213875.00 ns
**********************************
** Note: $finish    : C:/Users/User/Desktop/Bicubic/tb.sv(239)
   Time: 7213875 ns  Iteration: 1  Instance: /tb
```

Error pixels=8+14+14=36

Criteria

Grading policy(100%)

- Score – simulation (50%)
  - Class S (50 points): RTL & Gate-level all patterns pass
  - Class A (40 points): RTL pass & Gate-level total error pixels ≤ 10
  - Class B (35 points): RTL pass & Gate-level total error pixels ≤ 20
  - Class C (25 points): RTL pass & Gate-level total error pixels > 20
  - Class D (20 points): RTL total error pixels ≤ 10
  - Class E (15 points): RTL total error pixels ≤ 20
  - Class F (5 points): RTL total error pixels > 20
- PA (Class S、A、B only) (25%)
- Report (25%)

Criteria

- Grading policy - Performance & Area(25%)
  - Performance : Simulation time in Gate-level Simulation.
  - Area : Total logic elements + 500 * embedded Multipliers.
  - This 25 points need in Class S、A、B to attend the PA Ranking.
  - Top 10% got 25 points, Top 10%~20% got 22.5 points….

```
# Loading instances from Bicubic_7_1200mv_85c_v_slow.sdo
# Loading altera_ver.PRIM_GDFF_LOW
# ** Warning: Design size of 11383 statements exceeds ModelSim-Intel FPGA Starter Edition recommended capacity.
# Expect performance to be adversely affected.
# Loading timing data from Bicubic_7_1200mv_85c_v_slow.sdo
# ** Note: (vsim-3587) SDF Backannotation Successfully Completed.
#    Time: 0 ps  Iteration: 0  Instance: /tb File: C:/Users/User/Desktop/Bicubic/tb.sv


:  24 24 24 24 24 22 1e 16 06 0e 22 24 22 20 20 20 20 1f 1f 1f 1f 1f 1e 1d 1a
:  22 22 22 23 23 22 1e 16 07 0e 20 22 20 20 20 20 1f 1f 1f 1f 1f 1f 1f 1e 1a
:  1e 1e 1e 1b 1b 1c 17 11 09 0e 1a 1b 19 19 19 18 17 17 17 17 17 17 16 16 14 11
:  0f 0f 10 10 11 13 13 15 18 1a 1a 1b 1c 1e 1f 20 21 22 22 22 23 23 24 25 25 24
:  09 09 0a 0e 10 11 16 1b 21 22 20 21 23 26 28 2b 2e 2f 2e 2e 2f 30 31 32 34 36
:  22 22 22 22 22 20 1d 15 07 0e 20 21 20 1f 1f 20 20 1e 1b 19 19 17 16 16 16 15
: ---- error count           0

**********************************
**   Finish Simulation
**   Error pixels:        0
**   Simulation time:  7213875.00 ns
**********************************
: ** Note: $finish    : C:/Users/User/Desktop/Bicubic/tb.sv(246)
:    Time: 7213875 ns  Iteration: 1  Instance: /tb
```

Flow Status	Successful - Wed May 22 01:10:17 2024
Quartus Prime Version	17.1.0 Build 590 10/25/2017 SJ Lite Edition
Revision Name	Bicubic
Top-level Entity Name	Bicubic
Family	Cyclone IV E
Device	EP4CE115F29C7
Timing Models	Final
Total logic elements	3,531 / 114,480 (3 %)
Total registers	251
Total pins	86 / 529 (16 %)
Total virtual pins	0
Total memory bits	0 / 3,981,312 (0 %)
Embedded Multiplier 9-bit elements	68 / 532 (13 %)
Total PLLs	0 / 4 (0 %)

Simulation time=7213875ns

Area=3531+68*500=37531

Criteria

- Grading policy - Performance & Area(25%)
  - Please upload your PA every time you upload your code.
  - You can check your PA from the excel link.

	A	B	C	D	E	F	G
1	時間戳記	電子郵件地址	Student ID	Score	Gate level simulation time (ns)	Area (Total elements + 300*embedde	Performance * Area

  - No upload, no PA credit.
  - Report and code are submitted individually.

Final-Bicubic PA google form

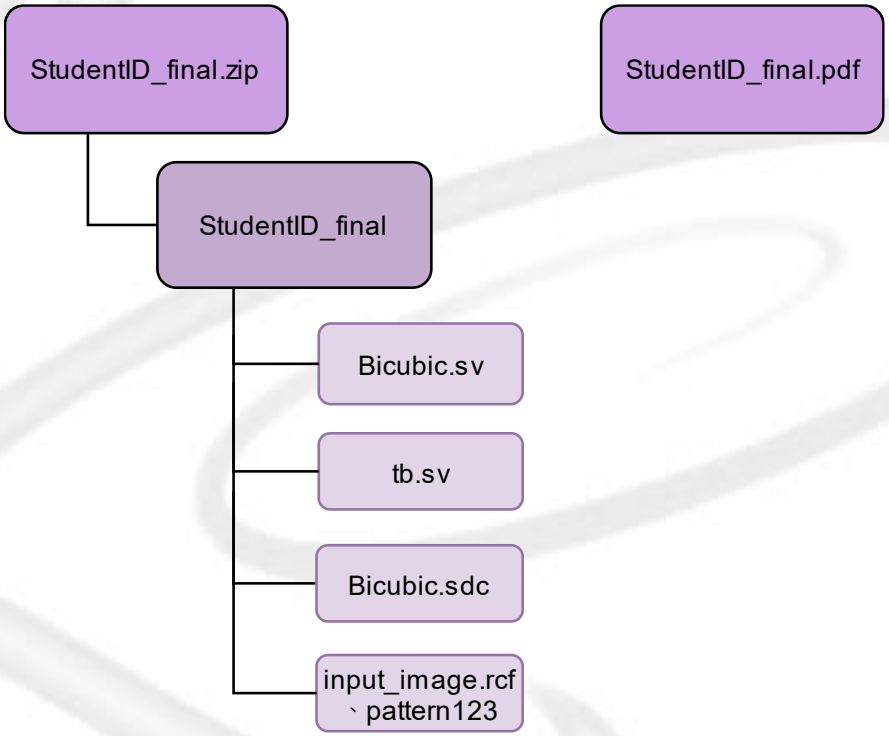
Final-Bicubic PA excel report

Final 繳交區 (code)(.zip)

Final 繳交區 (report)(.pdf)

Criteria

- File format
- Deadline:2024/06/13(Thu) 8:59 !!!



Criteria

Friendly reminder

- Please complete the assignment by your own, discussion with peers is recommended, but do not cheat.
- Warning! Any dishonesty found will result in zero grade.
- Warning! Designing responses tailored to the golden files will result in zero grade.
- Warning! Any late submission will also receive zero.
- Warning! Please make sure that your code can be compiled in Modelsim & Quartus, any dead body that we cannot compile will also receive zero.
- Warning! Please submit your work according to the specified file format, making sure not to include any unnecessary files. Any unnecessary file found, will lead to 10% deduction from the overall score.
- Please start this project As Soon As Possible, Quartus synthesize & Gate Level simulation will take you a lot of time.
- A bad coding style may cause your Gate Level simulation unsuccessful!!!

Thanks for listening

Appendix-1

- The coefficient of 3rd polynomial : $p(x) = ax^3 + bx^2 + cx + \mathrm{d}$, where 0≤x≤1.
  - Given the value of points p(-1), p(0), p(1) and p(2).
  - So p(0)=d …… equation1 ; p(1)=a+b+c+d …… equation2
  - Define the slope at point p(0) is $\frac{p(1)-p(-1)}{2}$; at point p(1) is $\frac{p(2)-p(0)}{2}$
  - Because p'(x) = $3ax^2 + 2bx + c$, p'(0) = c = $\frac{p(1)-p(-1)}{2}$ …… equation3
  - p'(1) = 3a+$2b + c$ = $\frac{p(2)-p(0)}{2}$ …… equation4
  - By solving equation 1~4 simultaneously, we can obtain:
    - a = $\frac{-1}{2}p(-1) + \frac{3}{2}p(0) - \frac{3}{2}p(1) + \frac{1}{2}p(2)$
    - b = $p(-1) - \frac{5}{2}p(0) + 2p(1) - \frac{1}{2}p(2)$
    - c = $\frac{-1}{2}p(-1) + \frac{1}{2}p(1)$
    - d = $p(0)$

Appendix-2

Pattern1

- The “source” data refer to the range selected from original image.
- The “target” data represents the result after enlarging.

pattern1 : (H0 V0) = (10 68) , (SW SH) = (13 13) , (TW TH)=(19 19)

source

4d	6	17	4f	50	51	50	3a	37	4f	4e	4c	4b	49	48
4c	3f	4c	4c	4f	4f	4f	3a	36	4f	4e	4c	4b	4a	48
4b	4c	f	1c	4e	4f	4f	38	35	4e	4d	4d	4b	4a	48
49	4a	3a	49	4a	4e	4e	38	35	4d	4c	4c	4b	4a	49
48	49	4a	c	2	45	46	32	2f	45	44	43	43	42	41
3e	48	4a	3b	76	6	22	19	19	22	20	20	20	1f	1c
12	46	49	49	1c	22	4b	36	34	4c	4c	4b	4b	4a	49
ad	2a	46	49	4a	26	16	35	32	4c	4c	4b	4b	4a	49
bb	46	44	46	49	40	50	16	32	4b	4b	4b	4b	4a	49
90	bb	6	46	46	48	2c	5c	27	4b	4a	4a	4b	4a	4a
40	ab	99	2a	46	46	48	13	3e	48	4a	4a	4a	4a	4a
24	51	bc	5e	3c	46	46	46	1a	13	4a	4a	4a	4a	4a
1e	1a	7c	bd	27	45	46	46	46	1c	1	4a	4a	49	49
1c	1c	30	b0	bc	6	46	46	46	44	32	6	4a	49	49
1f	2d	2e	34	a6	bb	6	46	46	46	43	25	10	46	49

target

3f	48	4d	4c	4e	4f	4f	51	49	3a	35	3d	4f	4f	4d	4c	4b	4b	4a
4a	2c	1d	27	43	52	4f	51	48	39	34	3c	4e	4e	4d	4d	4c	4b	4a
4c	25	16	28	45	52	4f	51	48	38	33	3c	4e	4e	4d	4d	4c	4b	4a
4a	3e	3d	49	4a	4b	4e	50	48	38	33	3c	4d	4d	4c	4c	4b	4b	4a
49	4b	3a	1c	e	20	4c	50	45	36	31	39	4a	4a	49	48	48	48	47
49	4e	3b	15	1d	27	31	39	35	29	26	2c	38	38	37	36	36	36	35
48	4b	44	3b	6c	58	6	16	21	19	18	1c	22	21	20	20	20	20	1f
49	4b	4a	47	3e	2b	17	35	3e	2d	29	31	3e	3f	3e	3d	3d	3d	3c
3d	45	4b	4a	2f	20	24	36	3d	39	34	3d	4f	50	4f	4e	4e	4e	4d
2a	39	49	49	4c	40	26	17	1e	35	32	39	4c	4d	4c	4b	4b	4b	4a
34	3e	4a	47	4b	46	38	3f	34	1a	28	3b	4b	4c	4b	4b	4b	4b	4a
6b	3a	2f	47	49	47	44	49	40	2b	2a	36	4b	4c	4b	4b	4b	4b	4a
bb	38	c	46	48	48	48	31	3a	5c	36	2e	4b	4c	4a	4a	4b	4b	4a
bb	89	51	2e	3e	49	47	43	36	27	32	41	4d	4c	4a	4a	4a	4a	4a
91	b5	8d	34	3b	45	46	4b	3c	1d	2b	36	38	47	4d	4a	4a	4a	4a
51	a5	a9	5e	42	3c	46	46	48	46	28	13	13	39	4e	4a	4a	4a	4a
27	74	a7	a4	46	24	4a	49	47	48	3f	2d	14	d	25	4f	4e	4a	49
16	43	88	c5	7b	3e	2c	3f	4a	46	4a	41	28	e	13	35	47	4d	49
1c	21	57	b0	cb	85	6	2c	4b	46	46	46	44	3b	21	6	34	4f	49

Appendix-3

Pattern2

pattern2：(H0 V0) = (81 18)，(SW SH) = (17 15)，(TW TH)=(22 28)

source

39	38	37	25	78	cb	96	6a	6d	72	73	71	73	76	79	7a	7c	83	8a
29	3a	39	38	1f	8d	ca	8f	6a	6c	6e	6e	71	75	77	78	7f	80	81
61	27	3a	39	38	16	a4	bc	7c	69	6b	6d	6e	72	76	7c	7b	7a	7c
1e	5c	2d	3a	3a	39	6	c8	b6	6e	69	6b	6d	72	7a	78	76	78	7a
3e	17	55	2b	3b	3a	39	22	c7	ac	68	69	6e	79	75	72	73	75	77
40	3f	6	71	3a	3b	3a	34	57	c7	8f	6b	77	72	6e	6e	71	73	7b
40	40	3f	57	12	3d	3c	3b	26	95	bc	7d	6e	6a	6b	6d	70	7b	81
41	41	40	6	44	16	3d	3d	3b	6	d1	af	66	67	69	6b	78	7e	78
41	41	41	e	2e	60	2f	3e	3d	38	58	c6	82	66	67	6e	74	71	70
41	41	41	e	41	11	30	3f	3e	3d	1c	c3	b1	67	66	6b	6b	6c	6e
25	25	25	6	25	25	53	1	3f	3e	3d	24	c4	8e	64	67	68	6a	6c
2e	2f	2e	c	2e	2e	14	65	3c	3f	3e	2c	a9	b1	65	64	66	68	6e
42	43	43	10	43	43	43	6	5	41	40	3f	22	c2	89	63	65	6b	7c
42	43	43	11	43	43	43	3c	5e	3a	41	40	2c	ac	b7	62	68	78	73
42	43	43	11	44	45	44	43	6	1	41	41	3f	2a	c1	85	75	72	69
42	43	43	11	44	45	45	45	3b	5d	3c	41	40	1c	c0	af	6b	64	64
42	42	43	11	44	45	45	45	45	e	d	43	42	40	63	b5	67	60	62

target

3a	3a	3a	2f	21	79	bb	be	8a	6d	69	6d	6e	6e	70	73	76	77	77	7b	80	80
2d	37	3c	34	27	3c	95	c6	a3	75	69	6a	6c	6d	6e	71	74	76	79	7c	7e	7d
28	35	3b	3a	37	11	63	b5	ba	86	6e	68	6b	6d	6d	70	73	76	7b	7c	7b	7a
49	34	34	3c	3a	24	2c	72	d3	a6	78	64	6a	6c	6c	6f	72	79	7a	7a	78	79
5a	37	31	3a	3a	3d	c	37	c8	bf	8b	69	69	6b	6c	6f	73	7a	79	77	76	78
31	48	3a	2d	3b	3d	25	2b	6b	c4	af	7e	63	69	6c	71	77	78	76	74	74	76
17	47	41	30	3b	3a	3d	2c	25	b0	c3	97	66	68	6c	73	79	74	72	72	73	75
2e	1c	3f	58	3d	3a	3d	32	2a	75	b6	b1	78	69	70	76	74	70	70	70	71	73
41	b	41	6b	34	3a	3c	38	36	43	9e	bf	8f	6e	72	75	70	6d	6e	6f	71	74
41	2b	4f	58	1a	39	3f	3b	38	29	82	bb	a9	78	70	6f	6c	6c	6d	6e	71	78
40	42	4a	3e	17	31	3c	3d	3a	23	59	a0	c1	8a	71	69	69	6b	6c	6e	73	7c
41	44	2a	1e	38	1d	2e	40	3c	36	1d	65	db	a8	75	62	68	6a	6a	70	78	7e
41	45	1b	e	44	26	2f	3d	3e	40	b	42	c8	bb	80	63	66	69	6a	71	7a	7c
41	45	21	f	34	52	42	33	3f	3e	2a	40	83	c1	92	6c	65	67	6c	72	76	74
42	46	25	13	33	52	3e	30	41	3d	3c	38	50	c5	a8	79	62	67	6c	70	72	6f
43	47	24	18	3f	23	24	35	44	3e	3f	2c	32	c5	bf	89	60	66	6b	6c	6d	6d
3a	3d	1f	15	3b	15	28	39	2d	3c	41	2e	2a	91	bb	9e	6a	66	69	6a	6a	6b
28	2b	15	c	29	20	43	3c	4	38	41	3c	36	34	a0	b6	7e	65	66	69	68	6a
25	27	13	c	26	27	3a	37	1f	3d	40	41	3a	15	92	c1	91	64	63	67	67	69
2d	2e	19	11	2d	2e	1c	2d	60	43	3d	40	3b	24	8a	be	a2	65	62	65	66	68
37	39	1e	15	37	38	26	2c	49	28	35	42	3d	31	5f	9d	b4	72	64	64	66	68
42	45	24	19	43	43	44	30	8	2	2c	45	40	3e	26	6b	c3	87	69	61	66	6a
44	48	26	19	45	45	49	37	13	23	39	43	41	42	1a	5f	c7	a0	6d	5e	68	71
43	46	25	19	44	44	43	3f	3b	5a	49	3c	41	41	27	61	bb	b7	74	5d	6b	78
43	46	25	19	44	45	44	44	42	3d	26	27	43	41	33	4a	83	be	84	69	71	77
43	46	25	1a	45	46	45	46	3f	d	0	17	44	41	40	2f	42	be	98	79	74	72
43	46	25	1a	45	46	45	46	41	1c	26	37	42	41	44	27	2f	c3	ae	85	6e	6b
43	46	25	1a	45	46	45	45	44	3a	53	54	3b	41	43	29	31	bc	bd	8e	65	64

Appendix-4

Pattern3

pattern3：(H0 V0) = (45 45)，(SW SH) = (16 29)，(TW TH)=(26 37)

source

45	46	49	4b	4c	45	25	4e	4c	4b	49	46	4e	bc	c0	c3	c7	76
2e	4b	4d	4f	50	48	27	51	51	50	4e	4b	4a	b9	be	c0	c4	74
9f	13	39	52	53	4d	2c	54	54	52	50	4e	48	b5	ba	be	c2	72
b1	ae	ac	1f	39	4f	2f	58	57	55	54	51	45	b3	b7	bb	bf	73
ae	ac	a9	a7	a6	25	13	5a	5a	57	56	53	42	b0	b4	b9	bd	c2
ad	aa	a8	a6	a4	a3	8c	15	4c	4b	48	45	4f	af	b2	b7	bb	c0
ac	a9	a7	a4	a3	a0	a0	93	c	3e	3c	3a	5a	ad	b2	b5	ba	c0
4c	a9	a6	a4	a1	a0	a0	9f	52	57	5a	57	3e	ac	b1	b4	b9	bf
50	1c	5c	a4	a1	a0	9f	9e	9f	2b	5b	58	3e	ac	b1	b5	b9	75
52	55	45	45	a2	a1	a0	9f	a0	4	5a	58	3f	ad	b1	b5	b9	6b
50	54	56	30	a4	a2	a1	a1	a2	10	59	57	40	ae	b1	b6	ba	6c
4f	52	54	38	a5	a4	a3	a3	a3	4	57	55	42	af	b3	b7	bc	6d
4d	4f	50	17	a7	a7	a6	a6	a6	f	54	52	44	b2	b5	ba	be	6e
1c	6	49	ad	ab	aa	a9	a9	a9	3b	51	4f	46	b5	b8	bc	c1	71
b7	b4	b1	b0	ae	ad	ac	ad	1c	4f	4e	4c	4a	b8	bb	bf	c4	74
bb	b8	b5	b3	b2	b1	b0	43	44	4c	4b	48	4e	bc	bf	c3	c7	78
c0	bc	ba	b8	b5	a9	4e	32	3d	3b	3a	38	5d	c0	c4	c7	cb	81
c3	c1	8b	63	32	1	c	20	1f	1e	1c	1a	45	59	5c	5f	5f	64
2c	32	3b	3d	3e	36	17	3f	3f	3d	3b	3a	37	35	32	2f	29	4
32	34	35	37	38	31	12	3a	39	38	36	35	32	30	2d	2c	26	6
2f	30	32	32	32	2b	c	34	34	32	31	2f	2e	2c	2a	27	22	6
2c	2d	2d	2e	30	27	6	2e	2e	2d	2d	2b	2a	29	27	25	20	c
29	2a	2a	2b	2b	22	2	2b	2a	29	29	29	27	25	24	22	1f	e
27	27	27	27	27	1f	1	27	27	25	26	25	22	22	20	20	1c	f
26	26	25	25	25	1c	4	24	24	22	22	20	20	20	20	20	1c	f
24	24	24	24	22	1a	5	22	22	20	20	20	1f	1f	1f	1e	1a	f
22	22	22	22	22	1a	6	20	20	20	20	1f	1f	1f	1f	1f	1a	10
1c	1a	1a	17	18	11	c	18	18	18	17	16	16	16	16	16	11	15
6	6	6	c	f	18	25	1f	22	27	2c	30	30	32	34	37	3a	3a
24	22	22	22	20	19	6	20	20	1f	20	1f	1a	19	16	16	15	11
25	25	24	22	22	1a	6	20	20	20	20	20	20	20	20	20	20	c

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4b	4d	4d	4f	50	50	4d	42	29	34	51	53	51	50	4f	4e	4c	49	43	73	b9	c1	bf	c0	c5	c4
12	20	3c	51	57	54	52	46	2d	38	53	55	53	52	50	4f	4e	4b	42	71	b6	be	bc	be	c4	c2
68	75	6e	37	2c	3d	4d	4d	33	3c	56	58	56	54	53	52	51	4c	41	6e	b4	bb	b9	bb	c2	c0
b9	be	a2	53	45	57	4a	37	23	36	5b	5c	59	57	56	55	54	4e	3f	6c	b2	b9	b7	b9	be	be
ac	a9	aa	ac	b3	ab	5d	21	17	2e	54	5b	5a	57	56	55	54	4d	3e	6b	b0	b7	b5	b8	bb	bd
aa	a9	a8	a7	a6	a5	a0	97	8c	54	14	35	53	4e	4b	4a	47	46	46	73	af	b5	b3	b6	b9	bb
a9	a8	a7	a5	a4	a3	a5	a5	a3	8f	6a	33	1a	38	41	3d	39	3e	4f	7b	ae	b4	b3	b5	b8	ba
b1	b0	a9	a4	a3	a2	a0	a0	a1	a8	a1	4f	20	42	4d	48	46	45	48	72	ac	b4	b3	b3	b6	ba
8f	98	9d	a4	a5	a1	a0	a0	a0	a2	a0	7c	5e	53	55	5c	5d	53	3a	64	ac	b4	b2	b3	b7	b9
1c	3c	6b	9a	a8	a1	a0	a0	9f	9f	9e	a7	8d	3a	35	5b	5d	52	3b	65	ac	b4	b2	b4	ba	b9
48	45	47	50	74	a2	a5	a1	a0	a0	9f	ab	89	1b	1d	5a	5f	52	3c	66	ad	b4	b2	b4	bb	b9
58	53	47	30	5c	a3	a7	a1	a0	a0	a0	ac	89	1c	1d	5a	5e	52	3c	67	ae	b5	b2	b5	bc	b9
53	58	4f	30	5a	a4	a9	a3	a2	a2	a2	ad	8b	1f	1f	58	5c	51	3d	68	ae	b5	b3	b5	bc	bb
52	55	4d	32	5d	a5	aa	a4	a3	a3	a3	ae	8a	17	18	57	5b	50	3e	69	af	b6	b4	b6	bd	bc
52	56	45	12	46	a7	ae	a7	a6	a6	a6	b1	8d	1f	1c	54	58	4e	3f	6c	b2	b9	b6	b9	c0	be
f	2b	4f	74	93	aa	ab	a9	a8	a7	a8	b8	9f	3f	31	52	53	4d	40	6e	b4	bb	b8	ba	c1	c0
4c	60	83	b0	b8	ac	ab	ab	aa	b0	b1	88	60	4a	47	50	4f	4b	41	71	b6	bd	ba	bc	c3	c2
c0	bc	b7	b2	af	af	ae	af	b0	ad	9b	46	19	46	53	4e	4c	4a	44	74	b9	c0	bd	bf	c6	c5
b8	b6	b5	b3	b3	b2	b1	b3	b7	87	43	3e	45	4b	4c	4b	49	47	46	78	bc	c3	c0	c2	c9	c7
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c9	b4	9f	90	7e	6a	54	3e	27	20	25	28	29	28	27	26	22	2a	47	69	88	8d	8d	8f	91	91
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2f	2f	30	30	30	31	2f	23	b	16	31	33	31	30	30	2f	2e	2d	2c	2c	2b	2a	28	27	25	21
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28	28	28	28	28	28	25	1a	3	d	28	2a	28	26	26	27	27	25	23	23	23	22	21	20	1f	1d
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25	25	25	25	25	24	20	17	5	e	23	25	23	21	21	21	20	20	20	20	20	20	20	1f	1e	1b
24	24	24	24	24	22	1e	16	6	e	22	24	22	20	20	20	20	20	1f	1f	1f	1f	1f	1e	1d	1a
22	22	22	23	23	22	1e	16	7	e	20	22	20	20	20	20	1f	1f	1f	1f	1f	1f	1f	1f	1e	1a
1e	1e	1e	1b	1b	1c	17	11	9	e	1a	1b	19	19	19	18	17	17	17	17	17	17	16	16	14	11
f	f	10	10	11	13	13	15	18	1a	1a	1b	1c	1e	1f	20	21	22	22	22	23	23	24	25	25	24
9	9	a	e	10	11	16	1b	21	22	20	21	23	26	28	2b	2e	2f	2e	2e	2f	30	31	32	34	36
22	22	22	22	22	20	1d	15	7	e	20	21	20	1f	1f	20	20	1e	1b	19	19	17	16	16	16	15