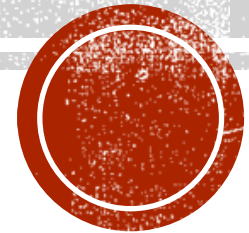


IMPLEMENTATION OF 16-POINT DFT USING OBC DA



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Matrix Form DFT (16-Point DFT)

$$\begin{matrix} \mathbf{Z} & = & \mathbf{C} & \mathbf{X} \end{matrix}$$

$$\begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \\ z_5 \\ z_6 \\ z_7 \\ z_8 \\ z_9 \\ z_{10} \\ z_{11} \\ z_{12} \\ z_{13} \\ z_{14} \\ z_{15} \\ z_{16} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & W & W^2 & W^3 & W^4 & W^5 & W^6 & W^7 & W^8 & W^9 & W^{10} & W^{11} & W^{12} & W^{13} & W^{14} & W^{15} \\ 1 & W^2 & W^4 & W^6 & W^8 & W^{10} & W^{12} & W^{14} & 1 & W^2 & W^4 & W^6 & W^8 & W^{10} & W^{12} & W^{14} \\ 1 & W^3 & W^6 & W^9 & W^{12} & W^{15} & W^2 & W^5 & W^8 & W^{11} & W^{14} & W & W^4 & W^7 & W^{10} & W^{13} \\ 1 & W^4 & W^8 & W^{12} & 1 & W^4 & W^8 & W^{12} & 1 & W^4 & W^8 & W^{12} & 1 & W^4 & W^8 & W^{12} \\ 1 & W^5 & W^{10} & W^{15} & W^4 & W^9 & W^{14} & W^3 & W^8 & W^{13} & W^2 & W^7 & W^{12} & W & W^6 & W^{11} \\ 1 & W^6 & W^{12} & W^2 & W^8 & W^{14} & W^4 & W^{10} & 1 & W^6 & W^{12} & W^2 & W^8 & W^{14} & W^4 & W^{10} \\ 1 & W^7 & W^{14} & W^5 & W^{12} & W^3 & W^{10} & W & W^8 & W^{15} & W^6 & W^{13} & W^4 & W^{11} & W^2 & W^9 \\ 1 & W^8 & 1 & W^8 & 1 & W^8 & 1 & W^8 & 1 & W^8 & 1 & W^8 & 1 & W^8 & 1 & W^8 \\ 1 & W^9 & W^2 & W^{11} & W^4 & W^{13} & W^6 & W^{15} & W^8 & W & W^{10} & W^3 & W^{12} & W^5 & W^{14} & W^7 \\ 1 & W^{10} & W^4 & W^{14} & W^8 & W^2 & W^{12} & W^6 & 1 & W^{10} & W^4 & W^8 & W^2 & W^{12} & W^6 & 1 \\ 1 & W^{11} & W^6 & W & W^{12} & W^7 & W^2 & W^{13} & W^8 & W^3 & W^{14} & W^9 & W^4 & W^{15} & W^{10} & W^5 \\ 1 & W^{12} & W^8 & W^4 & 1 & W^{12} & W^8 & W^4 & 1 & W^{12} & W^8 & W^4 & 1 & W^{12} & W^8 & W^4 \\ 1 & W^{13} & W^{10} & W^7 & W^4 & W & W^{14} & W^{11} & W^8 & W^5 & W^2 & W^{15} & W^{12} & W^9 & W^6 & W^3 \\ 1 & W^{14} & W^{12} & W^{10} & W^8 & W^6 & W^4 & W^2 & 1 & W^{14} & W^{12} & W^{10} & W^8 & W^6 & W^4 & W^2 \\ 1 & W^{15} & W^{14} & W^{13} & W^{12} & W^{11} & W^{10} & W^9 & W^8 & W^7 & W^6 & W^5 & W^4 & W^3 & W^2 & W \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \\ x_{11} \\ x_{12} \\ x_{13} \\ x_{14} \\ x_{15} \\ x_{16} \end{bmatrix}$$

$$W = e^{-j2\pi/N} \quad (N=16)$$

This is Matrix form of 16 point DFT which we have to implement



By solving, we will get these following equations

$$\begin{aligned}
 z_1 &= x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} \\
 z_2 &= x_1 + \omega x_2 + \omega^2 x_3 + \omega^3 x_4 + \omega^4 x_5 + \omega^5 x_6 + \omega^6 x_7 + \omega^7 x_8 + \omega^8 x_9 + \omega^9 x_{10} + \omega^{10} x_{11} + \omega^{11} x_{12} + \omega^{12} x_{13} + \\
 &\quad \omega^{13} x_{14} + \omega^{14} x_{15} + \omega^{15} x_{16} \\
 z_3 &= (x_1 + x_9) + (x_2 + x_{10}) \omega + (x_3 + x_{11}) \omega^2 + (x_4 + x_{12}) \omega^3 + (x_5 + x_{13}) \omega^4 + (x_6 + x_{14}) \omega^5 + (x_7 + x_{15}) \omega^6 + \\
 &\quad (x_8 + x_{16}) \omega^7 \\
 z_4 &= x_1 + \omega^3 x_2 + \omega^6 x_3 + \omega^9 x_4 + \omega^{12} x_5 + \omega^{15} x_6 + \omega^2 x_7 + \omega^5 x_8 + \omega^8 x_9 + \omega^{11} x_{10} + \omega^{14} x_{11} + \omega x_{12} + \omega^4 x_{13} + \omega^7 x_{14} + \\
 &\quad \omega^{10} x_{15} + \omega^{13} x_{16} \\
 z_5 &= (x_1 + x_5 + x_9 + x_{13}) + (x_2 + x_6 + x_{10} + x_{14}) \omega + (x_3 + x_7 + x_{11} + x_{15}) \omega^2 + (x_4 + x_8 + x_{12} + x_{16}) \omega^3 \\
 z_6 &= x_1 + x_2 \omega + \omega^4 x_3 + \omega^{10} x_4 + \omega^{15} x_5 + \omega^6 x_6 + \omega^9 x_7 + \omega^{14} x_8 + \omega^3 x_9 + \omega^8 x_{10} + \omega^{12} x_{11} + \omega^7 x_{12} + \\
 &\quad \omega^{13} x_{13} + \omega x_{14} + \omega^5 x_{15} + \omega^{11} x_{16} \\
 z_7 &= (x_1 + x_9) + (x_2 + x_{10}) \omega^2 + (x_3 + x_{11}) \omega^4 + (x_4 + x_{12}) \omega^6 + (x_5 + x_{13}) \omega^8 + (x_6 + x_{14}) \omega^{10} + (x_7 + x_{15}) \omega^{12} + \\
 &\quad (x_8 + x_{16}) \omega^{14} \\
 z_8 &= x_1 + \omega^7 x_2 + \omega^{14} x_3 + \omega^5 x_4 + \omega^{12} x_5 + \omega^3 x_6 + \omega^{10} x_7 + \omega x_8 + \omega^8 x_9 + \omega^{15} x_{10} + \omega^6 x_{11} + \omega^{13} x_{12} + \\
 &\quad \omega^4 x_{13} + \omega^{11} x_{14} + \omega^2 x_{15} + \omega^9 x_{16}
 \end{aligned}$$



$$Z_7 = x_1 + \omega^8 x_2 + x_3 + \omega^8 x_4 + x_5 + \omega^8 x_6 + x_7 \\ + \omega^8 x_8 + x_9 + \omega^8 x_{10} + x_{11} + \omega^8 x_{12} + x_{13} \\ + \omega^8 x_{14} + x_{15} + \omega^8 x_{16}$$

$$Z_9 = x_1 + x_3 + x_5 + x_7 + x_9 + x_{11} + x_{13} + x_{15} \\ + (x_2 + x_4 + x_6 + x_8 + x_{10} + x_{12} + x_{14} + x_{16}) \omega^8$$

$$Z_{10} = x_1 + \omega^9 x_2 + \omega^2 x_3 + \omega^{11} x_4 + \omega^4 x_5 + \omega^{13} x_6 + \\ \omega^6 x_7 + \omega^{15} x_8 + \omega^8 x_9 + \omega x_{10} + \omega^{10} x_{11} + \\ \omega^3 x_{12} + \omega^{12} x_{13} + \omega^5 x_{14} + \omega^{14} x_{15} + \omega^7 x_{16}$$

$$Z_{11} = x_1 + \omega^{10} x_2 + \omega^4 x_3 + \omega^{14} x_4 + \omega^5 x_5 + \omega^2 x_6 + \\ \omega^{12} x_7 + \omega^6 x_8 + \omega x_9 + \omega^{10} x_{10} + \omega^4 x_{11} + \\ \omega^{14} x_{12} + \omega^8 x_{13} + \omega^2 x_{14} + \omega^{12} x_{15} + \omega^6 x_{16}$$

$$Z_{11} = x_1 + x_9 + (x_2 + x_{10}) \omega^{10} + (x_3 + x_{11}) \omega^4 + (x_4 + x_{12}) \omega^{14} \\ + (x_5 + x_{13}) \omega^5 + (x_6 + x_{14}) \omega^2 + (x_7 + x_{15}) \omega^{12} \\ + (x_8 + x_{16}) \omega^6$$

$$Z_{12} = 1x_1 + \omega^{11}x_2 + \omega^6x_3 + \omega x_4 + \omega^{12}x_5 + \omega^7x_6 \\ + \omega^2x_7 + \omega^{13}x_8 + \omega^8x_9 + \omega^3x_{10} + \omega^{14}x_{11} \\ + \omega^9x_{12} + \omega^4x_{13} + \omega^{15}x_{14} + \omega^{10}x_{15} + \omega^5x_{16}$$

$$Z_{13} = x_1 + \omega^{12}x_2 + \omega^8x_3 + \omega^4x_4 + x_5 + \omega^{12}x_6 + \\ \omega^6x_7 + \omega^4x_8 + x_9 + \omega^{12}x_{10} + \omega^6x_{11} + \\ \omega^4x_{12} + x_{13} + \omega^{12}x_{14} + \omega^6x_{15} + \omega^4x_{16}$$

$$Z_{13} = x_1 + x_5 + x_9 + (x_2 + x_6 + x_{10})\omega^{12} + \omega^6(x_3 + x_7 + x_{11} + x_{15}) \\ + (x_4 + x_8 + x_{12} + x_{16})\omega^4$$

$$Z_{14} = x_1 + \omega^3x_2 + \omega^{10}x_3 + \omega^7x_4 + \omega^4x_5 + \omega x_6 + \\ \omega^{14}x_7 + \omega^1x_8 + \omega^8x_9 + \omega^5x_{10} + \omega^2x_{11} + \\ \omega^{15}x_{12} + \omega^{12}x_{13} + \omega^9x_{14} + \omega^6x_{15} + \omega^5x_{16}$$

$$Z_{15} = x_1 + \omega^{14}x_2 + \omega^{12}x_3 + \omega^{10}x_4 + \omega^8x_5 + \omega^6x_6 \\ + \omega^4x_7 + \omega^2x_8 + x_9 + \omega^{14}x_{10} + \omega^{12}x_{11} + \\ \omega^{10}x_{12} + \omega^8x_{13} + \omega^6x_{14} + \omega^4x_{15} + \omega^2x_{16}$$

$$Z_{15} = x_1 + x_9 + (x_2 + x_{10})\omega^4 + \omega^{12}(x_3 + x_{11}) + \\ \omega^{10}(x_4 + x_{12}) + \omega^8(x_5 + x_{15}) + (x_6 + x_{14})\omega^6 \\ + (x_7 + x_{15})\omega^4 + (x_8 + x_{16})\omega^2$$

$$\begin{aligned}
 Z_{16} = & x_1 + \omega^{15}x_2 + \omega^{14}x_3 + \omega^{13}x_4 + \omega^{12}x_5 + \\
 & \omega^{11}x_6 + \omega^{10}x_7 + \omega^9x_8 + \omega^8x_9 + \omega^7x_{10} + \\
 & \omega^6x_{11} + \omega^5x_{12} + \omega^4x_{13} + \omega^3x_{14} + \omega^2x_{15} \\
 & + \omega x_{16}
 \end{aligned}$$



The above equations, I had implemented in Verilog using OBC DA architecture and then, these inputs are given

```
x0=32'd2;  
x1=32'd2;  
x2=32'd3;  
x3=32'd4;  
x4=32'd5;  
x5=32'd6;  
x6=32'd7;  
x7=32'd8;  
x8=32'd9;  
x9=32'd10;  
x10=32'd11;  
x11=32'd12;  
x12=32'd13;  
x13=32'd14;  
x14=32'd3;  
x15=32'd2;
```



outputs we got are faithful, all are in 2's complement representation

```
re0=000000000000000000000000000000001101111
re1=1111111111111111111111111111111110111
re2=1111111111111111111111111111111110111
re3=1111111111111111111111111111111110111
re4=000000000000000000000000000000000011
re5=1111111111111111111111111111111110111
re6=1111111111111111111111111111111110111
re7=1111111111111111111111111111111110111
re8=111111111111111111111111111111111011
re9=1111111111111111111111111111111110111
re10=1111111111111111111111111111111110111
re11=1111111111111111111111111111111110111
re12=00000000000000000000000000000000011
re13=1111111111111111111111111111111110111
re14=1111111111111111111111111111111110111
re15=1111111111111111111111111111111110111
im0=000000000000000000000000000000000000
im1=111111111111111111111111111111111000
im2=000000000000000000000000000000000100
im3=000000000000000000000000000000000100
im4=000000000000000000000000000000000110
im5=111111111111111111111111111111111000
im6=111111111111111111111111111111111100
im7=000000000000000000000000000000000100
im8=000000000000000000000000000000000000
im9=111111111111111111111111111111111000
im10=000000000000000000000000000000000100
im11=000000000000000000000000000000000100
im12=111111111111111111111111111111111010
im13=111111111111111111111111111111111000
im14=11111111111111111111111111111111100
im15=0000000000000000000000000000000001000
```



THANK YOU

