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step III =>

$x_3(k) = x_1(k) \times x_2(k)$

$x_3(0) = x_1(0) \times x_2(0)$

$= 10 \times 6 = 60$

$x_3(1) = x_1(1) \times x_2(1)$

$= (2-2j)\,0$

$= 0$

$x_3(2) = x_1(2) \times x_2(2)$

$= 2 \times 2$

$= 4$

$x_3(3) = x_1(3) \times x_2(3)$

$= (2+2j) \times 0$

$= 0$

$x_3(k) = \{60, 0, 4, 0\}.$

step 4 => $x_3(n) = \frac{1}{4} W_4^{-1} x_3(k)$

$$x_3(n) = \frac{1}{4}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & J & -1 & -J \\ 1 & -1 & 1 & -1 \\ 1 & -J & -1 & J \end{bmatrix}\begin{bmatrix} 60 \\ 0 \\ 4 \\ 0 \end{bmatrix} = \begin{bmatrix} 60 & 0 & 4 & 0 \\ 60 & 0 & -4 & 0 \\ 60 & 0 & 4 & 0 \\ 60 & 0 & -4 & 0 \end{bmatrix}$$

$$= \frac{1}{4}\begin{bmatrix} 64 \\ 56 \\ 64 \\ 56 \end{bmatrix}$$

$x_2(k) = \{1, 2, 3, 4\}$

$$W_4 x_2(k) = \begin{bmatrix} W_4^1 & W_4^1 & W_4^1 & W_4^1 \\ W_4^1 & W_4^1 & W_4^2 & W_4^3 \\ W_4^1 & W_4^2 & W_4^4 & W_4^6 \\ W_4^1 & W_4^3 & W_4^6 & W_4^9 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 & 4 \\ 1 & -2j & -3 & 4j \\ 1 & -2 & 3 & -4 \\ 1 & 2j & -3 & -4j \end{bmatrix}$$

$$= \begin{bmatrix} 10 \\ -2+2j \\ -2 \\ -2-2j \end{bmatrix}$$

$x_2(k) = \{10, -2+2j, -2, -2-2j\}$

$x_3(k) = x_1(k) \times x_2(k)$

$x_3(0) = x_1(0) \times x_2(0)$

$= 6 \times 10$

$= 60$

$x_3(1) = x_1(1) \times x_2(1)$

$= 0 \times (-2+2j)$

$= 0$

$x_3(2) = x_1(2) \times x_2(2)$

$= 2 \times -2$

$= -4$

$x_3(3) = (-2-2j) \times 0$

$= 0$

$$\boxed{\frac{1}{4} = \frac{1}{4}}$$

$x_3(k) = \{60, 0, -4, 0\}$.

$x_3(n) = \frac{1}{4}(\omega)_4^{-1} x_3(k)$

$$= \frac{1}{4}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & J & -1 & -J \\ 1 & -1 & 1 & -1 \\ 1 & -J & -1 & J \end{bmatrix}\begin{bmatrix} 60 \\ 0 \\ -4 \\ 0 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 60 & 0+4 \\ 60 & 0+4 \\ 60 & 0-4 \\ 60 & 0+4 \end{bmatrix}$$

$$= \cancel{\begin{bmatrix} 64 \\ 56 \\ 64 \\ 56 \end{bmatrix}} = \frac{1}{4}\begin{bmatrix} 56 \\ 60 \\ 56 \\ 60 \end{bmatrix}$$

$x_3(n) = \frac{1}{4}\{58, 60, 58, 60\}$

$x_3(n) = \{14, 160, 14, 60\}$

Qu* Find the ~~following~~ linear convolution of following sequence.

$\Rightarrow x(n) = \{1, 2\}$, $h(n) = \{2, 1\}$.

For $x(n)$, $L - 1 = 1$

$L = 2$

For $h(n)$, $m - 1 = 1$

$m = 2$

$N = L + m - 1$

$N = 2 + 2 - 1 = 3$

~~3 dft~~

∴ Here we ~~can~~ have to compute three point DFT we go DFT four point Here we add the zero

$x(n) = \{1, 2, 0, 0\}$

$h(n) = \{2, 2, 0, 0\}$

Step 1

$X(k) = W_4 \cdot x(n) = W_4\{1, 2, 0, 0\}$

$$W_4 \cdot x(n) = \begin{bmatrix} W_4^1 & W_4^1 & W_4^1 & W_4^1 \\ W_4^1 & W_4^1 & W_4^2 & W_4^3 \\ W_4^1 & W_4^2 & W_4^4 & W_4^6 \\ W_4^1 & W_4^3 & W_4^6 & W_4^9 \end{bmatrix} = \begin{bmatrix} 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -J & -1 & J \\ 1 & -1 & & -1 \\ 1 & J & -1 & -J \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 0 & 0 \\ 1 & -2j & 0 & 0 \\ 1 & -2 & 0 & 0 \\ 1 & 2j & 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 3 \\ 1-j2 \\ -1 \\ 1+2j \end{bmatrix}$$

$X(k) = \{3, 1-2j, -1, 1+2j\}$.

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$x_2(k) = \omega_{N_4}\, h_2(n) =$

$$\omega_{N_4}\, h_2(n) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 2 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 1 & 0 & 0 \\ 2 & -j & 0 & 0 \\ 2 & -1 & 0 & 0 \\ 2 & j & 0 & 0 \end{bmatrix} = \begin{bmatrix} 3 \\ 2-j \\ 1 \\ 2+j \end{bmatrix}$$

$h_2(k) = \{3,\ 2+j,\ 1,\ 2+j\}$.

step III $\Rightarrow$

$Y_3(k) = x_2(k) \times h_2(k)$

$Y_3(0) = x_1(0) \times h_2(0)$
$= 3 \times 3$
$= 9$

$Y_3(1) = x_1(1) \times h_2(1)$
$= (1-2j)(2-j)$
$= -5j$

$Y_3(2) = x_1(2) \times h_2(2)$
$= -1 \times 1$
$= -1$

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$X_3(3) = X_1(3) \times X_2(3)$

$= (1+2j)(2+j)$

$= 5i$

$X_3(k) = \{9, -5i, -1, 5i\}$

step (IV) $x_3(n) = \frac{1}{4} W_4^{-1} X_3(k)$

$$= \frac{1}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & -j & -1 & j \end{bmatrix} \begin{bmatrix} 9 \\ -5i \\ -1 \\ 5i \end{bmatrix}$$

$$= \frac{1}{4} \begin{bmatrix} 9 & -5i & -1 & 5i \\ 9 & 5 & 1 & 5 \\ 9 & 5i & -1 & -5i \\ 9 & -5 & 1 & -5 \end{bmatrix} = \frac{1}{4} \begin{bmatrix} 8 \\ 20 \\ 8 \\ 0 \end{bmatrix} = \begin{bmatrix} 2 \\ 5 \\ 2 \\ 0 \end{bmatrix}$$

$x_3(n) = \{2, 5, 2, 0\}$

$A = 1$

$(s+1)(s+2)$ | $s =$

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Ex. Compute the circular convolution $x_1(n) = \{1, 2, 3, 4\}$, $x_2(n) = \{4, 5, 6, 7\}$ by using DFT & IDFT formula.

$\Rightarrow$ According to DFT formula.

step I)

$$x_1(k) = \sum_{n=0}^{N-1} x_1(n) e^{\frac{-j2\pi kn}{N}}$$

$k = 0$ to 3

$N - 1 = 3$

$N = 4$

$$x_1(k) = \sum_{n=0}^{4} x_1(n) e^{\frac{-j2\pi kn}{4}}$$

$$x_1(k) = x_1(0) e^{\frac{-j2\pi k0}{4}} + x_1(1) e^{\frac{-j2\pi k}{4}} + x(2) e^{\frac{-j4\pi k}{4}} + x(3) e^{\frac{-j6\pi k}{4}}$$

$$x_1(k) = x_1(0) e^0 + x(1) e^{\frac{-j\pi k}{2}} + x(2) e^{-j\pi k} + x(3) e$$

$$x(k) = 1e^0 + 2e^{\frac{-j\pi k}{2}} + 3e^{-j\pi k} + 4e^{\frac{-j3\pi k}{2}}$$

put $k = 0$

$x(0) = 1 + 2 + 3 + 4 = 10$

$(x(0) = 10)$

Put $k = 1$

$$x(1) = 1 + 2e^{-j\pi/2} + 3e^{-j\pi} + 4e^{\frac{-j3\pi}{2}}$$

$= 1 + 2(\cos \pi/2 - j\sin \pi/2) + 3[\cos\pi - j\sin\pi] + 4(\cos 3\pi$
$\sin 3\pi$

$$\boxed{X(1) = -2+2j}$$

Put $k = 2$

$$x(2) = 1 + 2e^{\frac{-j\pi 2}{2}} + 3e^{-j2\pi} + 4e^{\frac{-j3\times 2\pi}{2}}$$

$$\boxed{X(2) = -2}$$

Put $k = 3$

$$x(3) = 1 + 2e^{\frac{-j3\pi}{2}} + 3e^{-j3\pi} + 4e^{\frac{j3\times 3\pi}{2}}$$

$\cancel{\boxed{x(3) = -2-2j}}$ $\boxed{x(3) = -2-2j}$

$$x_1(k) = \{10,\ -2+2j,\ -2,\ -2-2j\}$$

step 2 ⇒

$$x_2(k) = \sum_{n=0}^{N-1} x_2(n)\, e^{\frac{-j2\pi kn}{N}}$$

$K = 0$ to 3

$N-1 = 3$

$N = 4$

$$x_2(k) = \sum_{n=0}^{4} x_2(n)\, e^{\frac{-j2\pi kn}{4}}$$

$$x_2(k) = x_2(0)e^0 + x_2(1)e^{\frac{j2\pi k}{4}} + x_2(2)e^{-j\pi k} + x_2(3)e^{\frac{-j3\pi k}{4}}$$

$$x_2(k) = 4e^0 + 5e^{j2\pi k/4} + 6e^{j\pi k} + 7e^{\frac{-j3\pi k}{4}}$$

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Put $k=0$

$x_2(0) = 4e^0 + 5e^0 + 6e^0 + 7e^0$

$x_2(0) = 22$

Put $k=1$

$x_2(1) = 4e^0 + 5e^{\frac{-j\pi k}{2}} + 6e^{-j\pi} + 7e^{\frac{j3\pi k}{2}}$

$x_2(1) = -2+2j$

Put $k=2$

$x_2(2) = 4e^0 + 5e^{-j\pi k} + 6e^{j2\pi} + 7e^{j3\pi}$

$\boxed{x_2(2) = -2}$

Put $k=3$

$x_2(3) = 4e^0 + 5e^{\frac{-j3\pi k}{2}} + 6e^{-j3\pi} + 7e^{-j9\pi/2}$

$= -2-2j$

$x_2(K) = \{22, -2+2j, -2, -2-2j\}$.

Step 3 ⇒

$x_3(k) = x_1(k) \times x_2(k)$

$x_3(0) = x_1(0) \times x_2(0)$

$= 10 \times 22$

$\boxed{x_3(0) = 220}$

$x_3(1) = x_1(1) \times x_2(1)$

$= (-2+2j)(-2+2j)$

$\boxed{x_3(1) = -8i}$

$x_3(2) = x_1(2) \times x_2(2)$

$= -2 \times -2$

$\boxed{x_3(2) = 4}$

$x_3(3) = x_1(3) \times x_2(3)$

$= (-2-2j) \times (-2-2j)$

$\boxed{x_3(3) = 8i}$

$x_3(k) = \{220, -8i, 4, 8i\}$

~~sept~~ step 4 =>

$x_3(n)$

$$x_3(n) = \sum_{k=0}^{N-1} x(k)\, e^{\frac{+j2\pi k}{4}}$$

$$x_3(n) = \sum_{k=0}^{4} x(k)\, e^{\frac{j2\pi k}{4}}$$

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$x(n) = \{1, 0.5\}$, $h(n) = \{0.5, 1\}$.
linear.

=> According to DFT formula.

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{\frac{-j2\pi kn}{N}}$$

$\cancel{N-1=1}$, $\cancel{m-1=1}$
$\cancel{N=2}$, $\cancel{m=2}$

$k = 0$ to 3.

$\cancel{N = L+M-1}$
$\cancel{= 2+2-1}$
$\cancel{N=3}$

$N-1=3$
$N=3-1$
$N=4$
$x(n) = \{1, 0.5, 0, 0\}$
$h(n) = (0.5, 1, 0, 0\}$

$$X_1(k) = \sum_{n=0}^{3} x(n) e^{\frac{-j2\pi kn}{4}}$$

$$X(k) = x(0) e^{0} + x(1) e^{\frac{-j2\pi k}{4}} + x(2) e^{\frac{-j4\pi k}{4}} + x(3) e^{\frac{-j6\pi k}{4}}$$

$$\cancel{X(k) = x(0) e^{0} + x(1) e^{\frac{-j\pi k}{2}} +}$$

$$X(k) = 1e^{0} + 0.5 e^{\frac{-j\pi k}{2}} + 0 e^{-j\pi k} + 0 e^{\frac{-j3\pi k}{2}}$$

Put $k=0$

$X(0) = 1 + 0.5 = 1.5$

-4, 8, 8

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$x_3(n) = x(0)e^{j\pi} + x(1)e^{\frac{j\pi k}{2}} + x(2)e^{j\pi}$

$+ x(3)e^{\frac{j3\pi k}{2}}$

Put $k=0$

$x_3(0) = \frac{1}{4}(220e^0 + (-8j)e^0 + 4e^0 + (8j))$

$x_3(0) = \frac{1}{4}(224) = 56$

$x_3(1) = \frac{1}{4}(220e^0 + (-8j)e^{\frac{j\pi}{2}} + 4e^{j\pi} + (8j)e^{j3\pi/2})$

$\boxed{x_3(1) = \frac{1}{4}\, 58}$

$x_3(2) = \frac{1}{4}(220e^0 - 8ie^{j\pi} + 4e^{j2\pi} + 8ie)$

$\boxed{x_3(2) = 56}$

-8i - 8i

-8i

$x_4(3) = \frac{1}{4}(220e^0 - 8ie^{j3\pi/2} + 4e^{j3\pi} + 8ie)$

$x_3(3) = 58$

$\boxed{x_3(3) = 58}$

$x_3(n) = \{56, 58, 56, 58\}$

Put $k=1$

$$X(1) = 1 + 0.5e^{\frac{-j\pi}{2}}$$

$$= 1 + 0.5(\cos \pi/2 - j \sin \pi/2)$$

$$X(1) = 1 - 0.5i$$

Put $k=2$

$$X(2) = 1 + 0.5e^{-j\pi}$$

$$= 1 + 0.5(\cos \pi - j \sin \pi)$$

$$X(2) = 0.5$$

Put $k=3$

$$X(3) = 1 + 0.5e^{\frac{-j3\pi}{2}}$$

$$= 1 + 0.5(\cos 3\pi/2 - j \sin 3\pi/2)$$

$$X(3) = 1 + 0.5i$$

$$X(k) = \{1.5, 1-0.5j, 0.5, 1+0.5j\}.$$

step 2 =>

$$H(k) = \sum_{n=0}^{N-1} h(n)e^{\frac{-j2\pi kn}{N}}$$

$k = 0$ to 3

$N = 1 = 3$

$N = 4$

$$H(k) = \sum_{n=0}^{4} h(n)e^{\frac{-j2\pi kn}{4}}$$

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$h(k) = h(0)e^{0} + h(1)e^{-\frac{j\pi k}{2}} + h(2)e^{-j\pi k} + h(3)e^{-\frac{j3\pi k}{2}}$

$h(k) = 0.5e^{0} + 1\, e^{-j\pi k/2}$

Put $k=0$

$h(0) = 0.5e^{0} + e^{-\frac{j\pi}{2}}$

$h(0) = 0.5 - i$

put $k=1$

$h(1) = 0.5 + e^{-j\pi/2}$

$h(1) = 0.5 - i$

put $k=2$

$h(2) = 0.5 + e^{-j\pi}$

$h(2) = -0.5$

put $k=3$

$h(3) = 0.5 + e^{-j3\pi/2}$

$= 0.5 + 1$

$h(k) = \{0.5,\ 0.5 - i,\ -0.5,\ 0.5 + 1\}$.

step 3 =) $y_3(k) = x_1(k) \times x_2(k)$

$y_3(0) = x_1(0) \times x_2(0)$

$= 1.5 \times 0.5$

$= 0.75$

$y_3(1) = x_1(1) \times x_2(1)$

$= (1 - 0.5j)(0.5 - i)$

$y_3(1) = -1.25j$

$y_3(2) = x_1(2) \times x_2(2)$

$= (0.5) \times (-0.5)$

$= -0.25$

$y_3(3) = x_1(3) \times x_2(3)$

$= (1 + 0.5i) \times (0.5 + i)$

$= 1.25i$

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$y(k) = \{0.75, -1.25j, -0.25, 1.2$

Step 4 =>

$$y_3(n) = \frac{1}{4}\sum_{n=0}^{N-1} x(k)\, e^{j2\pi k n/N}$$

$$y_3(n) = \frac{1}{4}\sum_{n=0}^{4} x(k)\, e^{j2\pi k n/4}$$

$$y_3(n) = \frac{1}{4}\left[\sum x(0)\, e^{0} + x(1)\, e^{j2\pi n/4} + x(2)\, e^{j2\pi} + x(3)\, e^{j3\pi}\right.$$

Put $k=0$

$$y_3(0) = 0.75e^{0} - 1.25j\, e^{j2\pi} - 0.25e^{0} + 1.25j\, e^{0}$$

$$y_3(0) = 0.75 - 0.25 = \frac{1}{4}(0.5)$$

Put $k=1$

$$y_3(1) = \frac{1}{4}\left(0.75e^{0} - 1.25j\, e^{j\pi/2} + 0.25\, e^{j\pi} + 1.25j\, e\right.$$

$$y_3(1) = \frac{1}{4}(0.25 - 0.625i)$$

Put $n=2$

$$y_3(2) = \frac{1}{4}\left(0.75e^{0} - 1.25j\, e^{j\pi/4} - 0.25e^{j2\pi} + 1.25j\, e\right.$$

$$y_3(2) = \frac{1}{4}(1.125)$$

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$$X_3(3) = \frac{1}{4}\left(0.75e^{0} - 1.25e^{\frac{j3\pi}{2}} - 0.25e^{j3\pi} + 1.25e^{\frac{j9\pi}{2}}\right)$$

$$= 0.25 - 0.625j$$

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$$W_4^{kn} = e^{\frac{-j2\pi kn}{4}}$$

$n = 0$ to 3
$k = 0$ to 3
$N = 4$

1) $W_4^0 = e^{\frac{-j2\pi \times 0}{4}} = e^0 = 1$

2) $W_4^1 = e^{\frac{-j\pi}{2}} = \left(\cos \pi/_2 - j \sin \pi/_2\right) = -j$

3) $W_4^2 = e^{-j\pi} = \left(\cos\pi - j \sin\pi\right) = -1$

4) $W_4^3 = e^{-j3\pi/2} = \left(\cos \frac{3\pi}{2} - j \sin \frac{3\pi}{2}\right) = j$

5) $W_4^4 = e^{-j2\pi} = \left(\cos 2\pi - j \sin 2\pi\right) = 1$

6) $W_4^6 = e^{-j3\pi} = \left(\cos 3\pi - j \sin 3\pi\right) = -1$

7) $W_4^9 = e^{\frac{-j9\pi}{2}} = \left(\cos \frac{9\pi}{2} - \sin \frac{9\pi}{2}\right)$

$= -j$

$$W_4 = \begin{bmatrix} W_4^0 & W_4^0 & W_4^0 & W_4^0 \\ W_4^0 & W_4^1 & W_4^2 & W_4^3 \\ W_4^0 & W_4^2 & W_4^4 & W_4^6 \\ W_4^0 & W_4^3 & W_4^6 & W_4^9 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}$$

Que: Conclude DFT and IDFT and find circular convolution of following sequency

$(x(n))\ x_1 = \{4, 3, 2, 1\}$ $\quad h(n) = x_2 = \{2, 1, 2, 1\}$

To find $x_3(n) = ?$

$\Rightarrow$ we know that

$x_1(k) = W_N\, x_1$

step I $\Rightarrow$

$$W_4 = \begin{bmatrix} W_4^0 & W_4^0 & W_4^0 & W_4^0 \\ W_4^0 & W_4^1 & W_4^2 & W_4^3 \\ W_4^0 & W_4^2 & W_4^4 & W_4^6 \\ W_4^0 & W_4^3 & W_4^6 & W_4^9 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}$$

$X_1(k) = W_4^0\, x_1$

$$X_1(k) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 4 \\ 3 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 & 3 & 2 & 1 \\ 4 & -j3 & -2 & j \\ 4 & -3 & 2 & -1 \\ 4 & -j3 & -2 & -j \end{bmatrix}$$

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$$\begin{bmatrix} 4 & 3 & 2 & 1 \\ 4 & -3j & -2 & j \\ 4 & -3 & 2 & -1 \\ 4 & 3j & -2 & -j \end{bmatrix} = \begin{bmatrix} 10 \rightarrow x_1(0) \\ 2-2j \rightarrow x_1(1) \\ 2 \rightarrow x_1(2) \\ 2+2j \rightarrow x_4(3) \end{bmatrix}$$

$$X_1(k) = \{10,\ 2-2j,\ 2,\ 2+2j\}$$

step II $\Rightarrow$

$$X_2(k) = W_4\, x_2(n)$$

$$\begin{bmatrix} 4 & 3 & 2 & 1 \\ 4 & -3j & -2 & j \\ 4 & -3 & 2 & -1 \\ 4 & 3j & -2 & -j \end{bmatrix} \begin{bmatrix} \\ \\ \\ \\ \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} 2 \\ 1 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 & 1 & 2 & 1 \\ 2 & -j & -2 & j \\ 2 & -1 & 2 & -1 \\ 2 & j & -2 & -j \end{bmatrix}$$

$$X_2 = \begin{bmatrix} 6 \\ 0 \\ 2 \\ 0 \end{bmatrix} \begin{matrix} x_2(0) \\ x_2(1) \\ x_2(2) \\ x_2(3) \end{matrix}$$

$$X_2(k) = \{6,\ 0,\ 2,\ 0\}$$