SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF BIOMEDICAL ENGINEERING

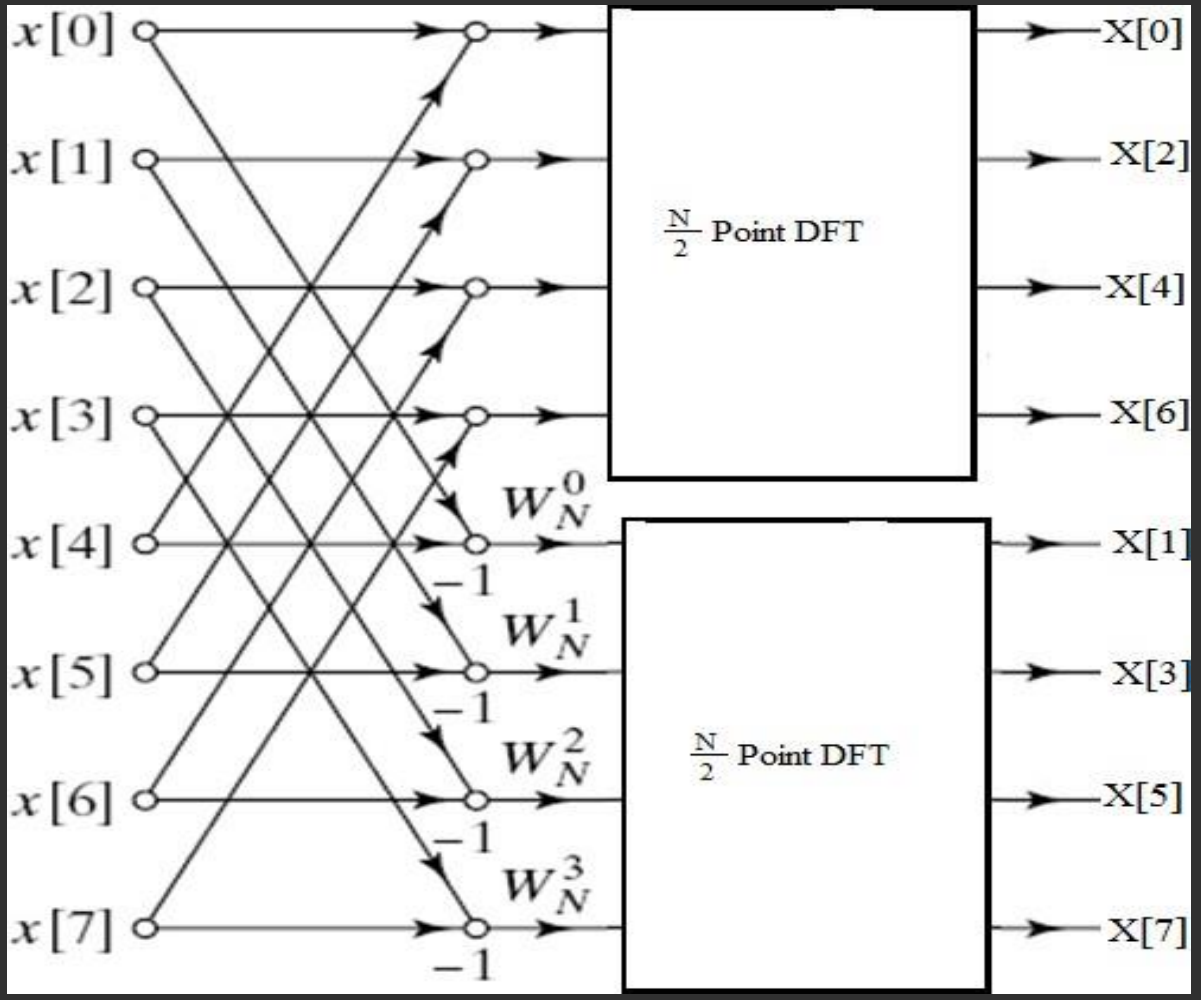
19BMB302 - BIOMEDICAL SIGNAL PROCESSING

III YEAR/ V SEMESTER

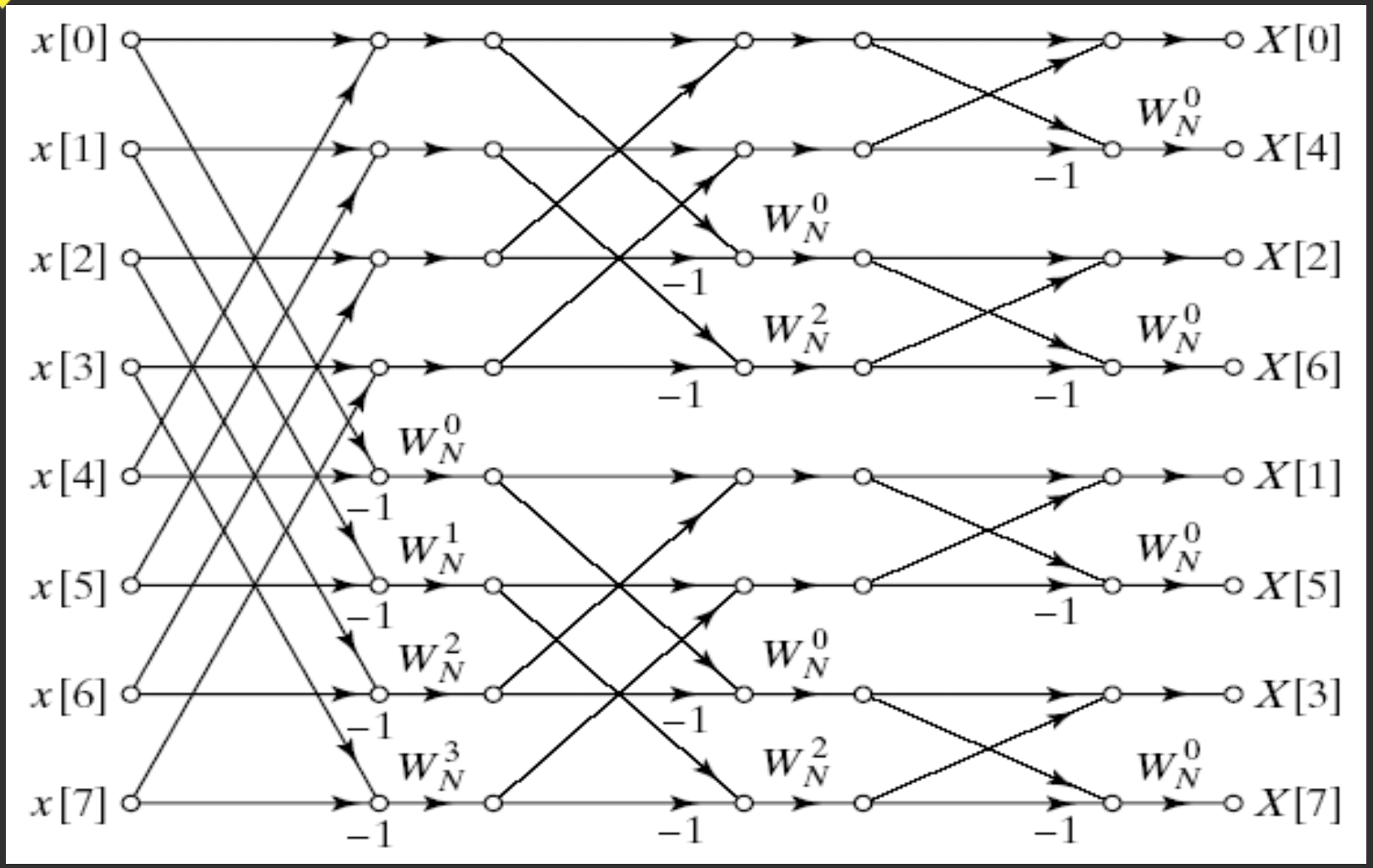
Unit 1 : TRANSFORMS

- Sampling theorem
- ECG signal conversion system
- Discrete Fourier Transform (DFT)
- Fast Fourier Transform (FFT)
- Decimation in time
- Decimation in frequency
- Multi rate Signal Processing
- Wavelet Transform.

Decimation-In-Frequency FFT Algorithm



DIF



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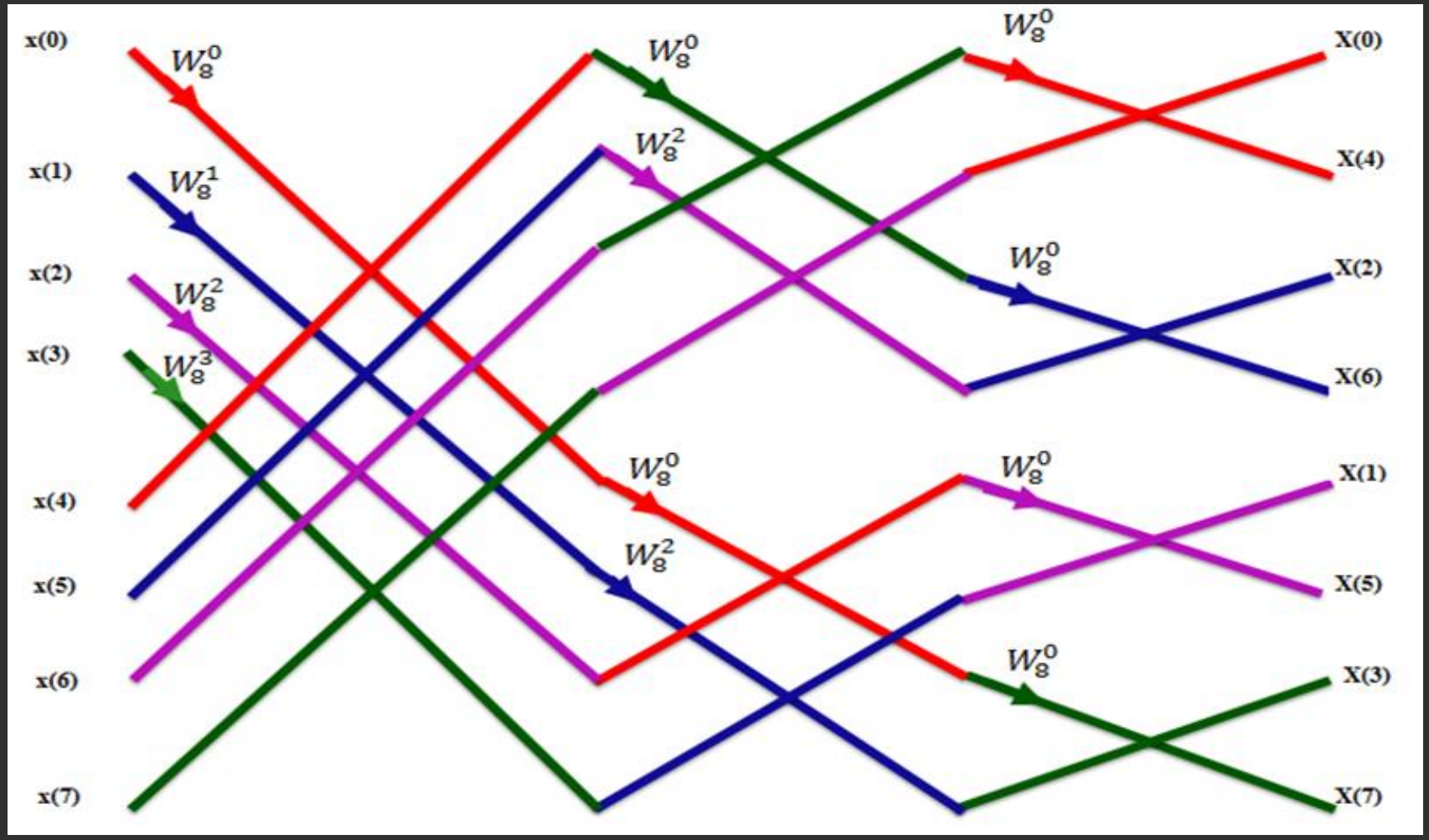


Steps in DIF FFT

4.7 Summary of Steps for Radix - 2 DIF-FFT Algorithm

1. The number of input samples $N = 2^M$, where, M is number of stages.
2. The input sequence is in natural order.
3. The number of stages in the flow graph is given by $M = \log_2 N$.
4. Each stage consists of $\frac{N}{2}$ butterflies.
5. Inputs/outputs for each butterfly are separated by 2^{M-m} samples, where m represents the stage index i e., for first stage $m = 1$ and for second stage $m = 2$ so on.
6. The number of complex multiplications is given by $\frac{N}{2} \log_2 N$.
7. The number of complex additions is given by $N \log_2 N$.
8. The twiddle factor exponents are a function of the stage index m and is given by

$$k = \frac{Nt}{2^{M-m+1}}, \quad t = 0, 1, 2, \ldots, 2^{M-m} - 1 \qquad (4.38)$$

9. The number of sets or sections of butterflies in each stage is given by the formula 2^{m-1}.
10. The exponent repeat factor (ERF), which is the number of times the exponent sequence associated with m repeated is given by 2^{m-1}.

Table 4.2 Comparison of number of complex multiplications for the direct evaluation of the DFT versus the FFT algorithm

Number of Stages M	Number of Points N	Number of Complex Multiplications Using		Speed Improvement Factor $\frac{N^2}{(N/2)\log_2 N}$
		Direct evaluation N^2	FFT algorithm $(N/2)\log_2 N$	
2	4	16	4	4
3	8	64	12	5.333
4	16	256	32	8
5	32	1,024	80	12.8
6	64	4,096	192	21.33
7	128	16,384	448	36.57
8	256	65,536	1024	64
9	512	2,62,144	2,304	113.77
10	1,024	10,48,576	5,120	204.8

Find the DFT of a sequence x(n)={1,2,3,4,4,3,2,1} using DIF algorithm.

N=8

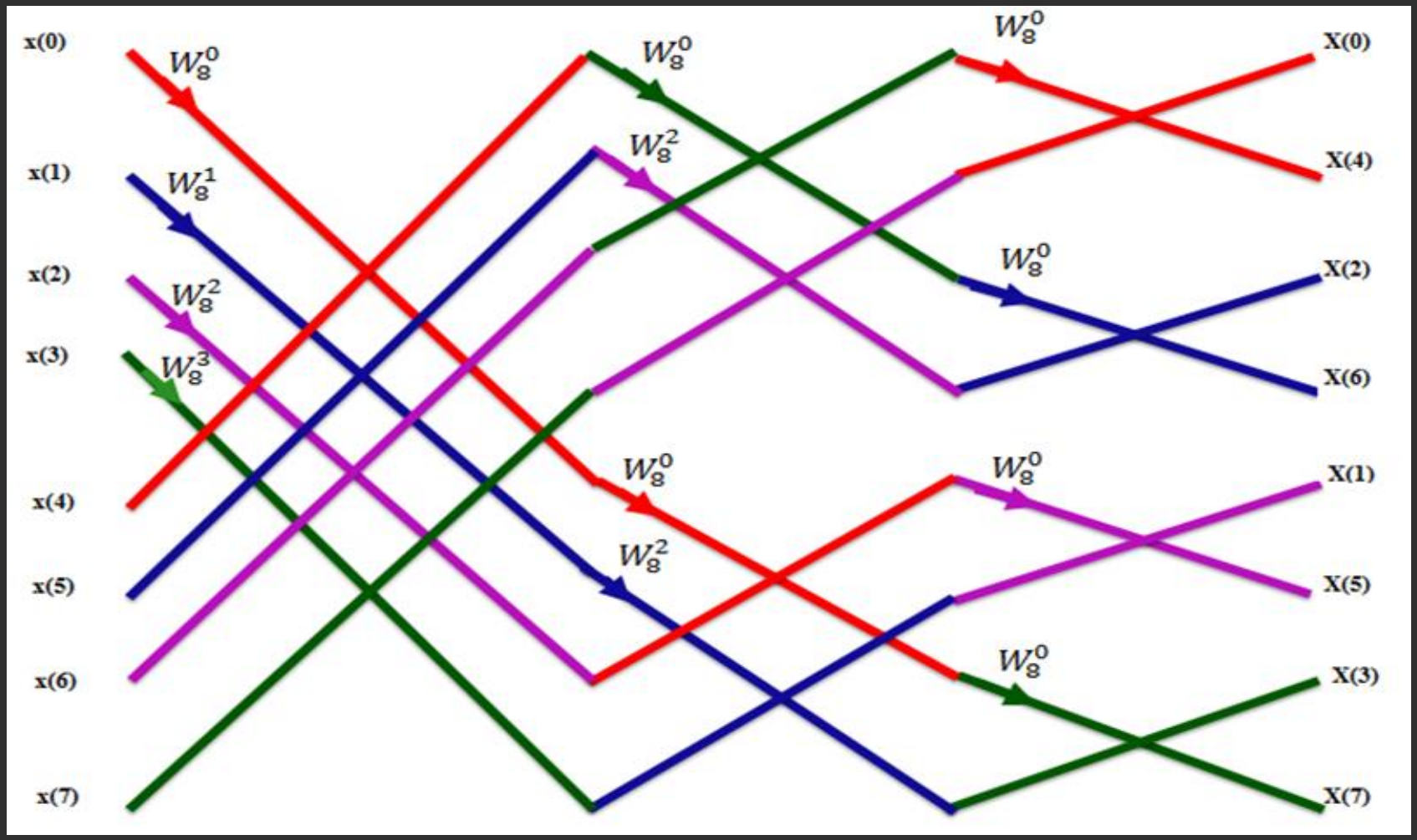
$$W_8^0 = e^{\left(\frac{-j2\pi}{8}\right)^0} = 1$$

$$W_8^1 = e^{\left(\frac{-j2\pi}{8}\right)^1} = 0.707 - \mathrm{j}\,0.707$$

$$W_8^2 = e^{\left(\frac{-j2\pi}{8}\right)^2} = -\mathrm{j}$$

$$W_8^3 = e^{\left(\frac{-j2\pi}{8}\right)^3} = -0.707 - \mathrm{j}\,0.707$$

DIF



Input	Stage 1 O/P	Stage 2 O/P	Output
1	1+4=5	5+5=10	10+10=20
2	2+3=5	5+5=10	10-10=0
3	3+2=5	(5-5)(1)=0	0
4	4+1=5	(5-5)(-j)=0	0
4	(1-4)(1)=-3	-3+(-j) = -3-j	(-3-j)+(-2.828-j1.414) =-5.828 - j2.414
3	(2-3) (0.707-j0.707) =-0.707+j0.707	(-0.707+j0.707)+ (-2.121-j2.121) =-2.828-j1.414	[(-3-j)-(-2.828-j1.414)](1) =-0.172 + j0.414
2	(3-2)(-j) = - j	(-3-(-j))(1)= -3 + j	(-3 + j)+(2.828-j1.414) =-0.172 - j0.414
1	(4-1) (-0.707-j0.707) =-2.121-j2.121	[(-0.707+j0.707)- (-2.121-j2.121)] (-j) =2.828-j1.414	[(-3 + j)-(2.828-j1.414)] (1) =-5.828 + j2.414

- X(k)={20, -5.828 - j2.414,0, -0.172 – j0.414,0, -0.172 + j0.414,0, -5.828 + j2.414}

Find the DFT of a sequence x(n)={1,1,1,1,1,1,1,1} using DIF algorithm.

N=8

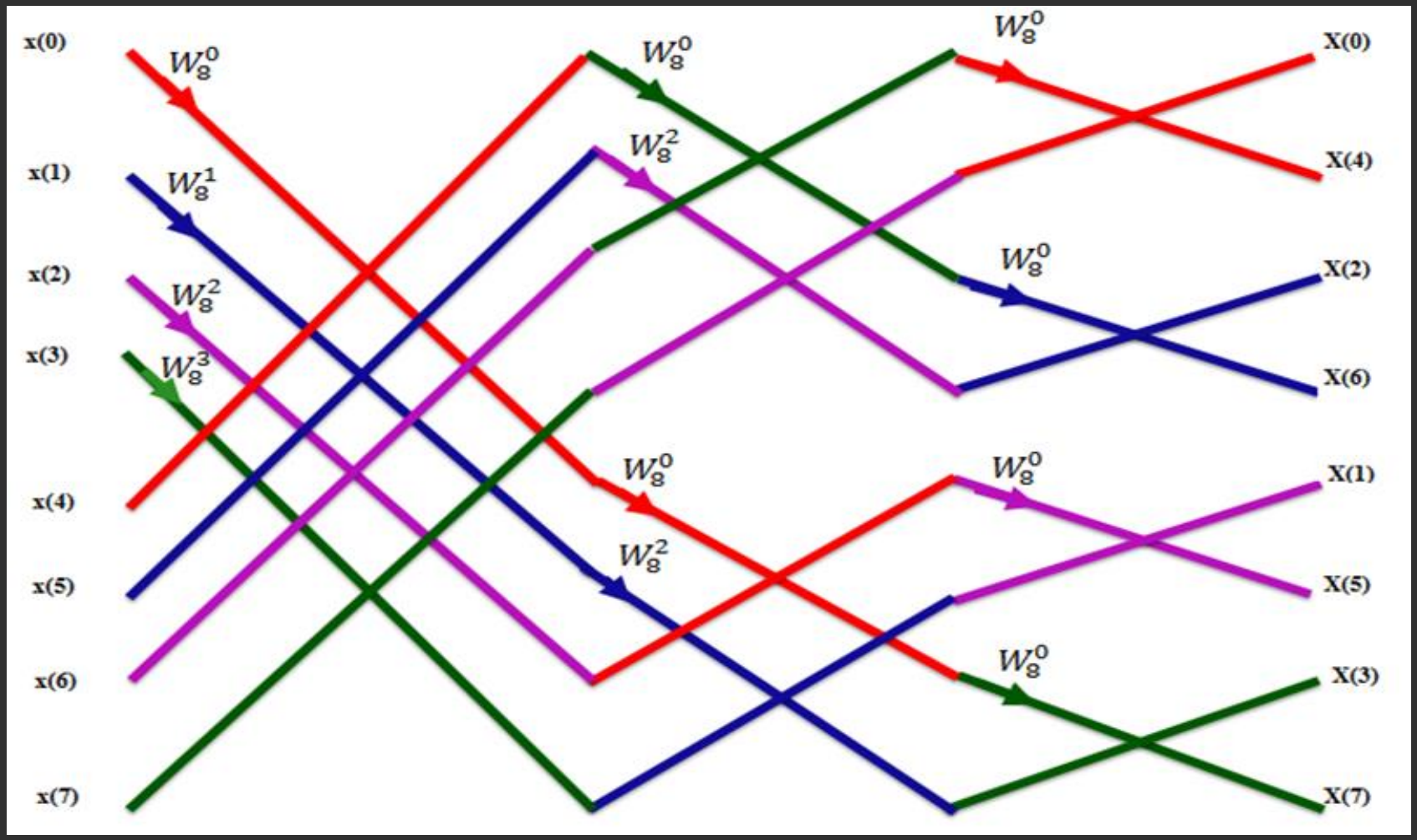
$$W_8^0 = e^{\left(\frac{-j2\pi}{8}\right)^0} = 1$$

$$W_8^1 = e^{\left(\frac{-j2\pi}{8}\right)^1} = 0.707 - \mathrm{j}\,0.707$$

$$W_8^2 = e^{\left(\frac{-j2\pi}{8}\right)^2} = -\mathrm{j}$$

$$W_8^3 = e^{\left(\frac{-j2\pi}{8}\right)^3} = -0.707 - \mathrm{j}\,0.707$$

DIF



Input	Stage 1 O/P	Stage 2 O/P	Output
1	1+1=2	2+2=4	4+4=8
1	1+1=2	2+2=4	4-4=0
1	1+1=2	(2-2)(1)=0	0
1	1+1=2	(2-2)(-j)=0	0
1	(1-1)(1)=0	0	0
1	(1-1)(0.707-j0.707)=0	0	0
1	(1-1)(-j) = 0	0	0
1	(1-1)(-0.707-j0.707) =0	0	0

X(k)={8,0,0,0,0,0,0,0}

Thank You!