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SUBJECT:	FOSIP
EXP. NO.:	3
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AIM: - The aim of this experiment is to study magnitude spectrum of the DT signal.

OBJECTIVES:
1. Develop a function to perform DFT of N point signal
2. Calculate DFT of a DT signal and Plot Spectrum of Signal.
3. Calculate the effect of zero padding on magnitude spectrum

INPUT SPECIFICATIONS:
1. Length of first Signal N
2. Signal values

PROBLEM DEFINITION:
1. Take any four-point sequence x[n].
   - Find DFT X[k].
   - Plot Magnitude Spectrum
2. Append the input signal by four zeros. Find DFT and plot Magnitude Spectrum. Give your conclusion.

WRITE UP ON DFT:
- **Introduction**

The Discrete Fourier Transform (DFT) is a powerful mathematical tool that plays a fundamental role in signal processing, data analysis, and various scientific and engineering applications. It allows us to analyze and understand the frequency components of a discrete, finite-length signal. The DFT has become an essential concept in fields such as telecommunications, audio processing, image analysis, and more. In this article, we will explore the basics of the DFT, its significance, and its applications.

- **The Basics of DFT**

The DFT is a mathematical transformation used to convert a sequence of discrete, time-domain data points into its frequency-domain representation. In simpler terms, it takes a signal that varies with time and decomposes it into its constituent sinusoidal components, revealing their amplitude and phase at various frequencies. This decomposition is particularly useful for understanding the underlying patterns, periodicities, and harmonics within the signal.

The mathematical expression for the DFT of a discrete signal can be defined as:

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

Where:

- X(K) represents the frequency component at index
- X[n] is a discrete signal in Time Domain
- N is the total number of data points.
- $e^{-j2\pi kn/N}$ is a complex exponential term that represents the contribution of the k-th frequency component.

- **Significance of DFT**

The DFT provides several critical advantages in signal analysis and processing:

  - **Frequency Analysis:** DFT is an invaluable tool for examining the spectral content of a signal. It helps in identifying dominant frequencies, harmonics, and noise within the data.

  - **Filtering:** It allows for the design and implementation of digital filters to remove unwanted frequencies from a signal, which is crucial in applications like audio noise reduction.

  - **Compression:** DFT is used in various compression techniques, such as the Fast Fourier Transform (FFT), which significantly reduces the computational complexity of the DFT and is employed in multimedia compression algorithms.

  - **Modulation and Demodulation:** In telecommunications, DFT plays a pivotal role in modulation and demodulation, enabling the transmission of information through different frequency carriers.

  - **Spectral Analysis:** It helps analyze complex phenomena in fields like climate science, where DFT can reveal periodic climate patterns, or in finance, where it can uncover recurring trends in market data.

- Applications of DFT

  - **Audio Processing**: In music and speech processing, the DFT is used for tasks like pitch detection, sound synthesis, and equalization.

  - **Image Analysis:** DFT is crucial in image processing for tasks like image compression, feature extraction, and image enhancement.

  - **Wireless Communications:** DFT is widely used in wireless communication systems to encode and decode information.

- **Medical Signal Analysis:** In fields like electrocardiography (ECG) and electroencephalography (EEG), DFT helps analyze signals to detect anomalies and diagnose medical conditions.

- **Radar and Sonar:** In radar and sonar systems, DFT assists in target detection and tracking by processing echo signals.

- **Astronomy:** DFT helps astronomers analyze light curves from distant stars and galaxies to determine their characteristics and behaviors.

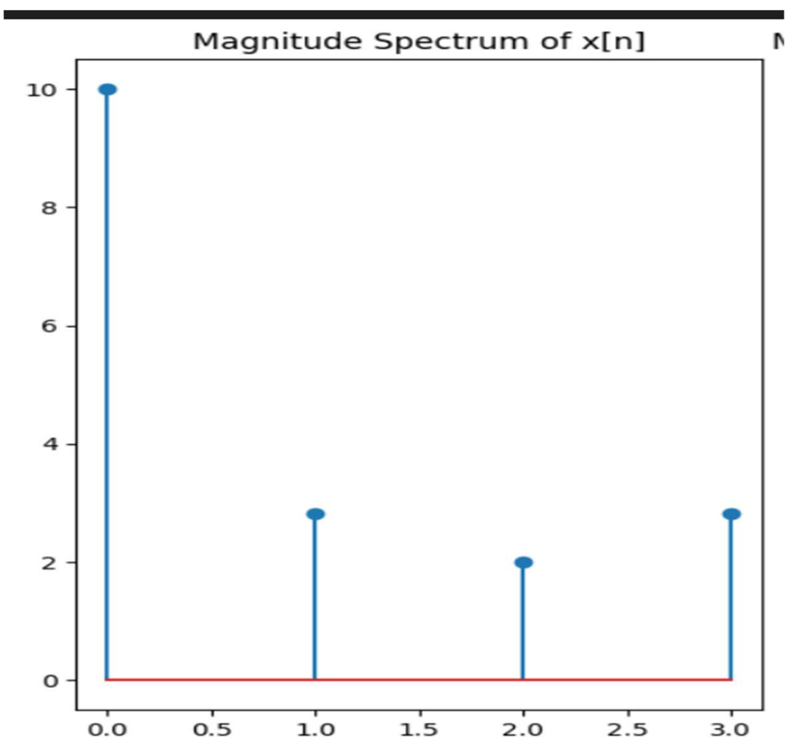
EXPERIMENTATION AND RESULT ANALYSIS

Case 1: To find DFT of Four-point Sequence

Input:

```
x = np.array([1, 2, 3, 4])
```

Output:




```
array([10.+0.00000000e+00j, -2.+2.00000000e+00j, -2.-9.79717439e-16j,
       -2.-2.00000000e+00j])
```

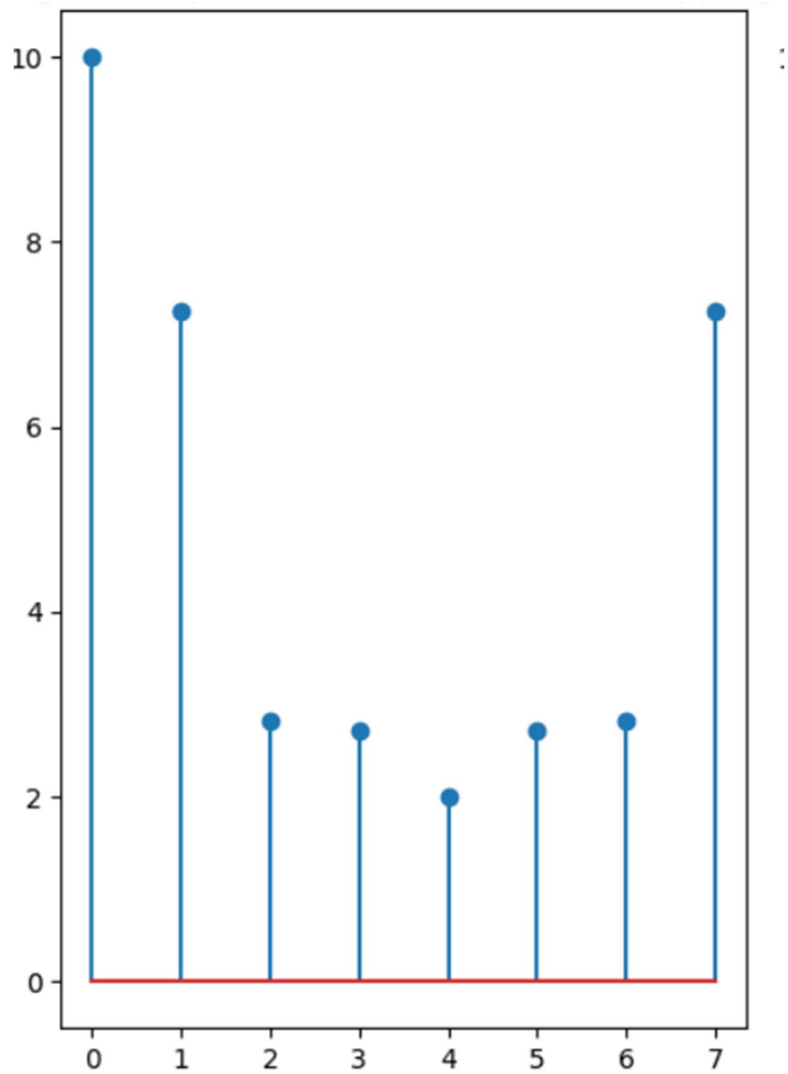
Case 2: To find DFT of zero padded signal

Input:

```
array([1, 2, 3, 4, 0, 0, 0, 0])
```

Output:

```
array([10.        +0.00000000e+00j, -0.41421356-7.24264069e+00j,
       -2.        +2.00000000e+00j,  2.41421356-1.24264069e+00j,
       -2.        -9.79717439e-16j,  2.41421356+1.24264069e+00j,
       -2.        -2.00000000e+00j, -0.41421356+7.24264069e+00j])
```



Case 3: To find DFT of expanded signal

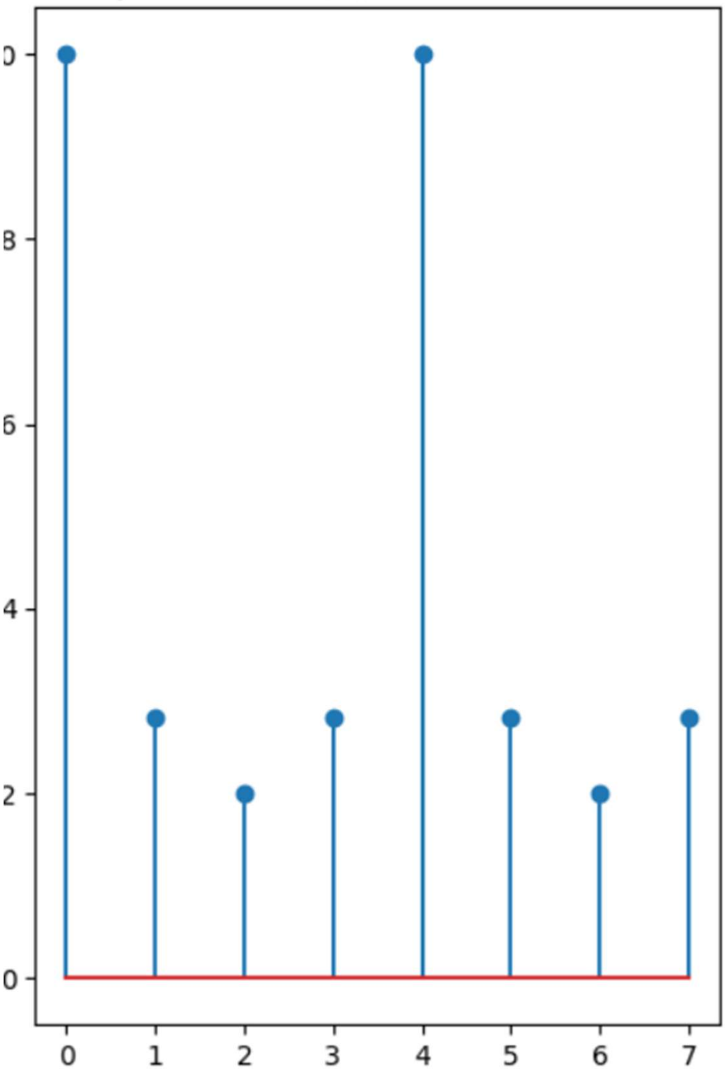
Input:

```
x_expanded = np.zeros(2 * len(x), dtype=complex)
x_expanded[::2] = x
x_expanded
✓ 0.0s

array([1.+0.j, 0.+0.j, 2.+0.j, 0.+0.j, 3.+0.j, 0.+0.j, 4.+0.j, 0.+0.j])
```

Output:

```
array([10.+0.00000000e+00j, -2.+2.00000000e+00j, -2.-9.79717439e-16j,
       -2.-2.00000000e+00j, 10.+4.89858720e-15j, -2.+2.00000000e+00j,
       -2.-2.93915232e-15j, -2.-2.00000000e+00j])
```



Conclusion:
1. The magnitude spectrum of the original 4-point sequence x[n] is plotted.
2. Appending 4 zeros to the input signal leads to a wider DFT spectrum with additional zero frequency components.
3. Expanding the input signal by inserting alternate zeros results in a wider DFT spectrum, with some zero frequency components.
4. DFT converts sequence from Time Domain to Frequency Domain
5. DFT Converts N samples from time domain to N coefficients in frequency domain
6. Frequency domain coefficients are separated by w = 2 π / N

The Application code file has been uploaded along with the detailed description of the procedure followed.