# Rajshahi University of Engineering & Technology

Department of Electrical & Computer Engineering

**Submitted by**

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**Course Title:** Digital Signal Processing Sessional

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**Submitted to**

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**Experiment No:** 04

**Experiment Name:**

1. Detection of Time Delay Using Cross-Correlation

2. Determination of Z-Transform

3. Determination of Zeros & Poles

**Experiment Date:** 14.05.2023

## Theory :

**Cross Correlation:** A mathematical method called cross-correlation is used in signal processing to calculate how similar two signals are in relation to their time delay. It is frequently used to identify and quantify the phase shift or time delay between two linked signals. In cross-correlation, the "test signal" is slid across the "reference signal" to compare it to another signal, the "reference signal," and to determine how similar the two signals are at each time point. This calculation yields a brand-new signal known as the cross-correlation function, which measures how similar the two signals are in relation to the gap in time between them.

**Z-Transform:** A mathematical transform known as the Z-transform is employed in the theory of control systems and digital signal processing. It is comparable to the continuous-time system's Laplace transform. A discrete-time signal, which is a series of values sampled at discrete time instants, is transformed into a complex-valued function of a complex variable, commonly abbreviated as Z, using the Z-transform. We can use the transform to examine the frequency content and Z-domain behavior of discrete-time signals.

The linearity, time reversal, and frequency reversal are only a few of the crucial characteristics of the Z-transform. It also offers a method to represent discrete-time system-describing difference equations in the Z-domain. A function in the Z-domain can be transformed back into the time domain using the inverse Z-transform. The inverse Z-transform can be calculated using a number of techniques, such as partial fraction expansion, power series expansion, and contour integration.

**Zeros & Poles:** A pole is a value of the complex variable Z for which the transfer function of a system becomes infinite or approaches infinity. A zero is a value of the complex variable Z for which the transfer function of a system becomes zero. The relative positions of poles and zeros in the Z-plane are crucial in determining the system's frequency response.

**Software:** MATLAB

**Code:**

**Time Delay of Two Signals Using Cross-Correlation:**

```
1.  clc;
2.  clear all;
3.  close all;
4.
5.  t = 0:0.01:20;
6.  a_1 = t>=10 & t<=15;
7.  a_2 = t>=12 & t<=15;
8.  signal_1 = a_1 + a_2;
9.  a_3 = t>=5 & t<=10;
10. a_4 = t>=7 & t<=10;
11. signal_2 = a_3 + a_4;
12.
13. [z,delay] = xcorr(signal_1, signal_2);
14. cross_correlation = z/max(abs(z(:)));
15.
16. subplot(3, 1, 1);
17. plot(t, signal_1);
18. title('Default Signal');
19.
20. subplot(3, 1, 2);
21. plot(t, signal_2);
22. title('Delayed Signal');
23.
24. subplot(3, 1, 3);
25. plot(delay*0.01, cross_correlation);
26. title('Cross Correlation');
27.
28. maximum = max(cross_correlation);
29. indexesOfMax = find(cross_correlation == maximum);
30. find_delay = delay(indexesOfMax);
31. temp = find_delay*0.01;
32. display = ['Time Delay is: ', num2str(temp), '
    seconds'];
33. disp(display);
```

**Z-Transform:**

```
clc;
clear all;
close all;

syms n z;
x = (1/5)^n + (1/9)^n;
X = ztrans(x, n, z);
disp(X);
```

**Zeros & Poles:**

```
clc;
clear all;
close all;

zeros = -0.2;
poles = 0.5*exp(j*2*pi*[-0.2 0.2]');
zplane(zeros,poles);
```

## Output:

### Time Delay of Two Signals Using Cross-Correlation:

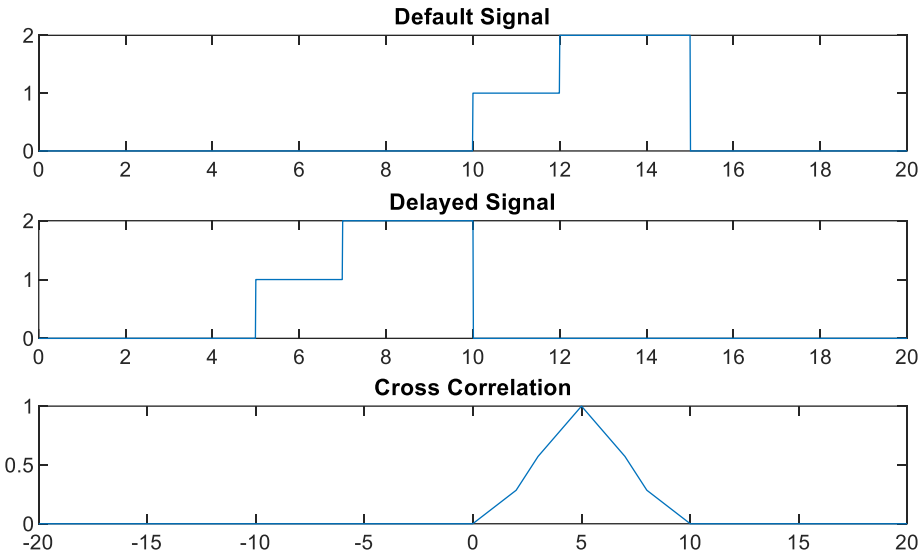


Fig 4.1 Time Delay of Two Signals Using Cross-Correlation

### Z-Transform:

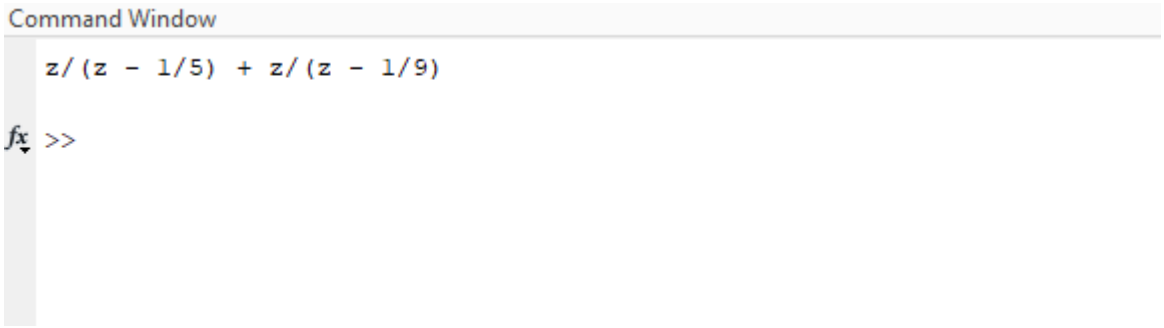


Fig 4.2 Determination of Z-Transform

**Zeros & Poles:**

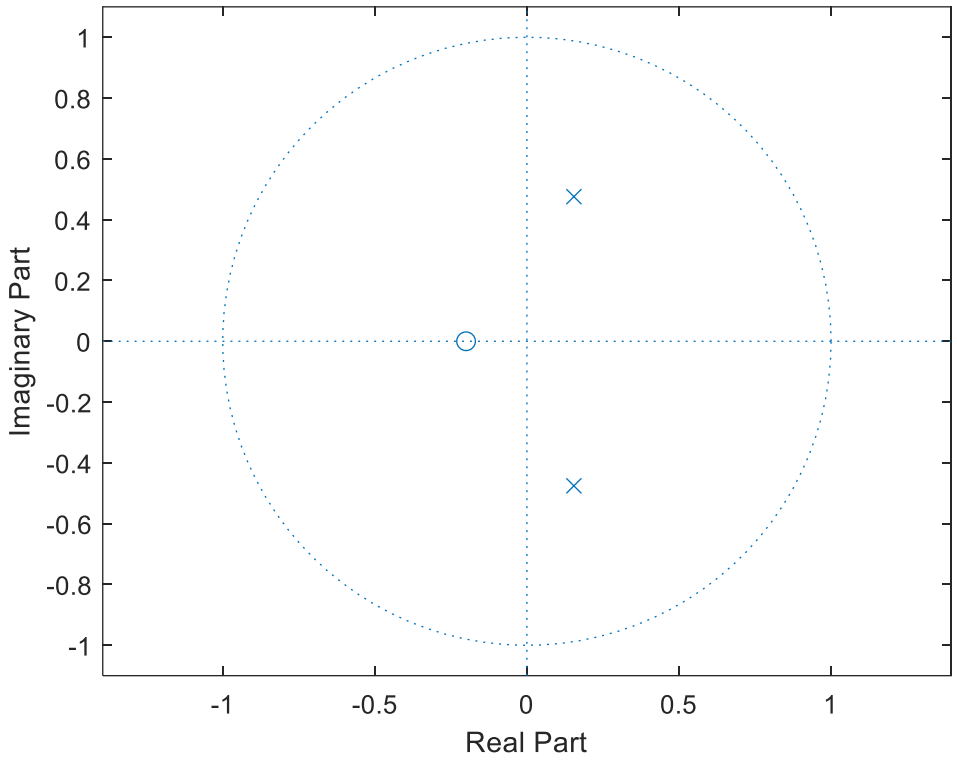


Fig 4.3 Determination of Zeros & Poles

**Discussion :** In this experiment, we learned how to use 'xcorr' function to determine the time delay between a signal and it's delayed version (using cross correlation) in MATLAB. Also, we observed Z-Transform and Zeros, Poles.

**Conclusion :** The graphs and results we got were as expected. The codes worked as intended and were executed without any errors. So, we can come to a conclusion that the experiments were done successfully.