Mini Project on

**Application of Z Transform**

Submitted in partial fulﬁllment of the requirements of the degree of

Bachelor of Engineering in Computer Science of Engineering (AIML)

Submitted by

**Ayush Khamkar - 21 Sameer Khan -22**

**Harshad Kolekar -23**

**Sahil Kudalkar -24**

Under the guidance of: **Prof. J.C jain**



**DEPARTMENT OF COMPUTER SCIENCE ENGINEERING**

**VIVA INSTITUTE OF TECHNOLOGY (AIML)**

At Shirgoan, Virar (East), Tal. Vasai, Dist. Palghar – 401305

2023-2024

**Application of Z**

**Transform**

**Group Number: 6**

Ayush Khamkar - 21 Sameer Khan -22

Harshad Kolekar -23

Sahil Kudalkar -24

**Acknowledgement**

In the accomplishment of this project successfully, many people have helped us and bestowed their heart-warming blessings and support.

I am taking this time to thank them for their concerned and support I would like to express my special thanks of gratitude to our professor Mr. Ramashankar Prajapati as well as our principal Dr. Arun Kumar who gave us the opportunity to work on this project on the topic ‘Z-Transform’, which also helped us understanding this topic ore clearly in which we came across many new things and diﬀerent applications on Function Of Square Matrix which were previously unknown to us.

Secondly, I would like to thank our team for giving their 100% and doing the project with their most sincere work and parents for supporting us while accomplishing this project successfully.

# Contents

1. Abstract
2. Introduction
3. Deﬁnition
4. Derivations
5. Applications
6. Problems
7. Conclusion
8. Bibliography

# Abstract

The Z-transform is a mathematical tool used in signal processing to analyze discrete-time signals. These signals are essentially sequences of numbers, as opposed to continuous-time signals which can have any value at any time. The Z-transform converts these discrete signals from the time domain (where they are represented by a sequence of values over time) into the z-domain (a complex number domain). This conversion allows for analysis of the signal's frequency content and behavior in a more convenient way using algebraic equations, rather than working directly with the time-based sequence In every square matrix, the number of rows and columns is equal. The sum of all principal

There are two main types of Z-transforms: unilateral and bilateral. The unilateral Z-transform is used for causal signals, where the signal's value at any given time only depends on past values, not future values. The bilateral Z-transform can handle non-causal signals as well.

The Z-transform is similar to the Laplace transform, which is used for continuous-time signals. It can be thought of as a discrete-time equivalent of the Laplace transform. Just as the Laplace transform is crucial for analyzing linear continuous-time systems, the Z-transform is essential for analyzing linear discrete-time systems. It is particularly useful for solving difference equations, which are equations that relate the present and past values of a signal to its future values. By converting the difference equation into the z-domain using the Z-transform, solving the equation becomes more straightforward using algebraic methods. The solution can then be converted back to the time domain to understand the signal's behavior over time There are diﬀerent types of square matrices:

# Introduction

The Z-transform is a mathematical tool widely used in digital signal processing (DSP) for analyzing discrete-time signals. Unlike continuous-time signals that can take on any value at any time, discrete-time signals are sequences of numbers representing the signal's value at specific points in time. The Z-transform bridges the gap between the time domain (where the signal is a sequence of values) and the z-domain (a complex number domain). This transformation allows us to analyze the signal's frequency content and behavior using algebraic manipulations in the z-domain, which can be much simpler than working directly with the time-based sequence

There are two main types of Z-transforms:

Unilateral Z-transform: Used for causal signals, where the present value of the signal depends only on past values, not future values. This is typical for real-world systems with a defined starting point.

Bilateral Z-transform: Applicable to both causal and non-causal signals.

Here's a simple analogy: Imagine a bouncing ball. The height of the ball at any given moment (time domain) depends on the initial push and previous bounces. The Z-transform helps us understand the bouncing pattern (frequency) by converting it into a mathematical equation in the z-domain.

Examples of Z-Transforms:

Step Function:

A common discrete-time signal is the unit step function, denoted as u(n), which is 1 for n ≥ 0 and 0 for n < 0. The Z-transform of u(n) is:

Z { u(n) } = Z { (..., 0, 0, 1, 1, 1, ...) } = 1/z

Impulse Function:

Another fundamental signal is the impulse function, δ(n), which is 1 for n = 0 and 0 for all other n. The Z-transform of δ(n) is:

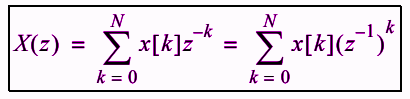
Z { δ(n) } = Z { (..., 0, 0, 1, 0, 0, ...) } = 1

# Deﬁnition

## Definition of Z-Transform

In mathematics and signal processing, the Z-transform converts a discrete-time signal, which is a sequence of real or complex numbers, into a complex frequency-domain representation

Also, it can be considered as a discrete-time equivalent of the [Laplace transform](https://byjus.com/maths/laplace-transform/).



Where,

x[n]= Finite length signal

[0, N] = Sequence support interval

z = Any complex number

N = Integer

X(z) = Z { x(n) } = Σ ( x(n) \* z^(-n) ), for all z in the region of convergence (ROC)

Σ (sigma) represents summation over all integer values of n (from negative to positive infinity for bilateral Z-transform, or from zero to positive infinity for unilateral Z-transform).

z is a complex number and the power -n indicates a negative exponent.

ROC is a set of values for z where the infinite sum converges.

Examples:

Shift Function:

The unit step function, denoted by u(n), is defined as:

u(n) = { 1, for n ≥ 0

{ 0, for n < 0

The Z-transform of u(n) is:

Z { u(n) } = Σ ( u(n) \* z^(-n) ) = 1/z (assuming ROC excludes z = 0)

This makes sense because multiplying a constant signal (1 in this case) by a negative power of z simply scales and shifts the function in the z-domain.

Delayed Impulse:

A delayed impulse function, δ(n-k), is defined as:

δ(n-k) = { 1, for n = k

{ 0, for n ≠ k

Here, k is a positive integer representing the delay. The Z-transform of δ(n-k) is:

Z { δ(n-k) } = z^(-k) (assuming ROC includes all non-zero z values)

This result shows that a delay in the time domain translates to a negative power of z in the z-domain.

These are just a couple of basic examples. The Z-transform can be applied to more complex signals by expressing them as a sum of simpler functions and using the linearity property of the transform. By leveraging the Z-domain, engineers can analyze and design digital filters, study system stability, and perform various other signal processing tasks.

**Applications**

1. Digital Signal Processing (DSP):
   * The Z-transform is a cornerstone of DSP. It allows for the analysis and design of digital filters, which are essential components in various technologies like
     + Mobile phones (removing noise from microphone input)
     + Digital television (enhancing image clarity).
     + Audio processing (equalizers, noise reduction)
     + Audio processing (equalizers, noise reduction).
2. Control System Analysis:
   * The Z-transform is vital for analyzing the behavior of discrete-time control systems. These systems are prevalent in various applications, including:

* Robotics (controlling robot movement)
* Engine control units (regulating engine performance)
* Industrial automation (controlling machinery operation)

1. Solving Difference Equations:
   * The Z-transform is a powerful tool for solving linear difference equations with constant coefficients. These equations are commonly used to model the behavior of discrete-time systems.
   * By transforming the difference equation into the z-domain, it can be converted into an algebraic equation, which is often much easier to solve. The solution can then be transformed back to the time domain to understand the system's response.
2. Analysis of Linear Time-Invariant (LTI) Systems:
   * The Z-transform is well-suited for analyzing LTI systems, which are fundamental building blocks in many engineering applications. These systems produce an output that depends only on the current and past inputs, and their properties remain constant over time

**Problems**

### Solved Problems

**Example 1:** Write the z-transform for a finite sequence given below.

x = {-2, -1, 1, 2, 3, 4, 5}

**Solution:**

Given sequence of sample numbers x[n]= is x = {-2, -1, 1, 2, 3, 4, 5}

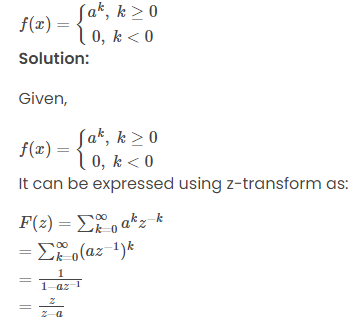
z-transform of x[n] can be written as:

X(z) = -2z0 – z-1 + z-2 + 2z-3 + 3z-4 + 4z-5 + 5z-6

This can be further simplified as below.

X(z) = -2 – z-1 + z-2 + 2z-3 + 3z-4 + 4z-5 + 5z-6

**Example 2:**Write the z-transform of the following power series



**Conclusion**

The Z-transform is a powerful mathematical tool that transforms discrete-time signals into the z-domain, enabling frequency analysis and manipulation. It plays a critical role in various applications like designing digital filters for noise reduction, analyzing and controlling robots and machines, and solving equations modeling discrete systems. Overall, the Z-transform empowers engineers to design, analyze, and optimize a vast range of digital systems across different fields!

**Bibliography**

<https://byjus.com/z-transformation-formula/>

<https://en.wikipedia.org/wiki/Z-transform>

<https://elec3004.uqcloud.net/2013/lectures/Lathi-Ch11-Discrete-Time%20System%20Analysis%20Using%20the%20Z-Transform.pdf>