### 1. Introduction To Linear System Analysis

- Definition of a System
- Simple Examples
- The General Problem
- Basic Concepts, Terms and Definitions
  - o Input-Output Relations
  - o Linearity
  - o Time-Invariance
  - o Causality
- Linear function
  - Matrix Multiplication representation
  - Engineering examples of linear systems and linear functions

# 2. Time-Domain Analysis of Input-Output Representation

## A. Continuous-Time Systems

- Elementary Functions
- Distribution Theory
- Resolution of Arbitrary Signals
- Impulse and Step Response
- Convolution Integrals

## **B.** Discrete-Time Systems

- Discrete-Time Impulse Function (Kronecker Delta Function)
- Discrete-Time Impulse Response
- Discrete-Time Convolution Sum and Solution

## 3. Frequency Domain Analysis of Continuous-Time Systems

- Fourier Series (for obtaining properties of signals)
  - o Properties of Fourier Series
  - Signal Spectra
- Fourier Transforms (for obtaining properties of systems)
  - o Properties of Fourier Transforms
  - System Response Function and its Spectra
  - o Fourier Series Coefficients From Fourier Transform
- Laplace Transforms

- Easier to Use Than Fourier Transforms
- o Limitations of Laplace Transforms
- Properties of Laplace Transforms
- Relationship to Fourier Transforms
- Applications of Fourier Series, Fourier Transform, and Laplace Transform
- Discrete-time Frequency response

#### 4. Least Square Approximation

- Linear Algebra: Norms, Cauchy-Schwartz Inequality, Basis, Rank of Matrix, Matrix norm
- Underdetermined and Overdetermined system
- Least square solution: Formulation and methods
- Estimation of Signal
- Practical Applications and Design of Systems

#### 5. State Variable Representation of Continuous-Time Systems

- Definition of State Vector
- Review of Matrix Algebra
- Representation in State-Variable form: Practical Examples
  - Companion Forms
  - o Jordan Form
  - o Similarity Transformations
  - Use of Software (MATLAB)

#### 6. Solution of the Continuous-Time State Equations

- The State Transition matrix
  - Properties
  - Method of Finding
- The Complete Solution

#### 7. Solution of the Discrete-Time State Equations

- The Discrete-Time Transition matrix
  - Properties
- The Complete Solution

#### 8. Higher Dimensional solution of Linear Dynamical Systems

• Matrix Exponential

- Characteristic Polynomial
- System Design
- Linear Dynamical Systems: Examples (Aircraft, Robotics)

### 9. Controllability and Observability of Linear Systems

- Definitions
- Examples of How Unwanted Uncontrollable and Unobservable Systems Can Arise
- The General Controllability Theorem (difficult to use)
- The Algebraic Controllability Theorem for time-invariant systems (easier to use)
- The General Observability Theorem (difficult to use)
- The Algebraic Observability Theorem for time-invariant systems (easier to use)

#### **10. Stability of Linear Systems**

- Continuous-Time Systems
  - Definitions
  - o Bounded-Input-Bounded-Output (BIBO) Stability
  - Internal Stability
- Discrete-Time Systems
  - $\circ$  Definitions
  - o Bounded-Input-Bounded-Output (BIBO) Stability
  - Internal Stability