Summary

1. Introduction

- Signals: Functions representing physical quantities varying with time, space, or any independent variable.
    - Examples: audio, video, temperature, ECG signals.
- Systems: Processes that manipulate or respond to signals.
    - Examples: filters, amplifiers, communication systems.

2. Types of Signals

- **Continuous-Time Signals (CT)**: Defined for every instant of time.
- **Discrete-Time Signals (DT)**: Defined only at discrete time intervals.
- **Analog Signals**: Continuous in amplitude and time.
- **Digital Signals**: Discrete in time and amplitude.
- **Deterministic vs. Random Signals**: Predictable vs. stochastic behavior.

3. Basic Signal Operations

- **Time Shifting**: x(t−t0)x(t-t_0)x(t−t0) or x[n−n0]x[n-n_0]x[n−n0]
- **Time Scaling**: x(at)x(at)x(at)
- **Time Reversal**: x(−t)x(-t)x(−t)
- **Amplitude Scaling**: a⋅x(t)a \cdot x(t)a⋅x(t)
- **Addition & Multiplication**: Combining signals for analysis or processing

4. Systems Properties

- **Linearity**: Obeys superposition (additivity + homogeneity)
- **Time-Invariance**: Output does not explicitly depend on absolute time
- **Causality**: Output depends only on present/past inputs
- **Stability**: Bounded input → Bounded output (BIBO stability)
- **Memoryless vs. Systems with Memory**: Dependence on past/future inputs

5. Signal Representation

- **Fourier Series**: Represents periodic signals as sum of sinusoids
- **Fourier Transform**: Represents aperiodic signals in frequency domain
- **Laplace Transform**: Generalizes Fourier Transform, useful for stability analysis
- **Z-Transform**: Discrete-time analog of Laplace Transform

6. System Analysis Techniques

- **Convolution**: y(t)=x(t)∗h(t)y(t) = x(t) * h(t)y(t)=x(t)∗h(t)
    - Key for LTI (Linear Time-Invariant) systems
- **Impulse Response**: Fundamental characterization of LTI systems
- **Frequency Response**: How system responds to different frequencies

7. Sampling and Reconstruction

- **Sampling Theorem (Nyquist)**: Sample at > 2× maximum frequency to avoid aliasing
- **Aliasing**: Overlapping of frequency components due to under-sampling
- **Reconstruction**: Using ideal low-pass filter to recover continuous signal

8. Modern Applications

- Digital signal processing (DSP)
- Communication systems
- Image and audio processing
- Control systems

9. Key Takeaways

- Signals and systems can be analyzed in both **time** and **frequency** domains.
- LTI systems are foundational because of **convolution** and **frequency response** simplicity.
- Sampling bridges the continuous and discrete worlds.
- Transform techniques (Fourier, Laplace, Z) simplify analysis of complex systems.