Lecture 14

Digital Signal Processing Summary & Problems

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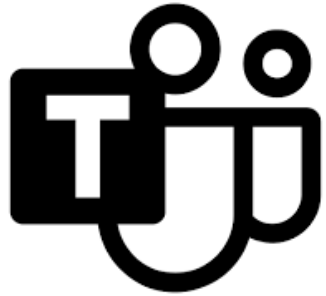
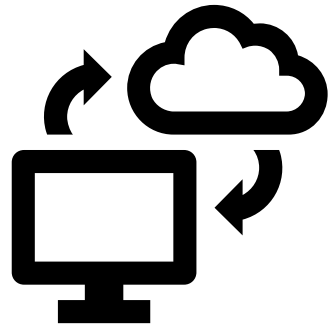




Digital Signal Processing

Outline

Digital Signal Processing Summary

Exam Example

Digital Signal Processing - Summary

Introduction to digital signal processing

- Continuous-time & discrete-time sinusoidal signals
- Normalized frequency
- Alias effect

Discrete-time signals & systems

- Discrete-time signals
  - Examples, classification & manipulation
- Discrete-time systems
  - Examples, block diagram representation, classification & interconnection

Digital Signal Processing - Summary

Analysis of discrete-time linear time-invariant systems

- Resolving signals as impulses
- Impulse response sequence
- Convolution sum & convolution properties
- Causality & BIBO stability
- Correlation of discrete-time signals
  - Cross-correlation & autocorrelation sequence
  - Correlation properties
  - Correlation of power signals

Digital Signal Processing - Summary

FIR and IIR causal systems

- Recursive & non-recursive discrete-time systems
- Free & forced response

Direct-forms for discrete-time systems

- IIR systems: direct-form I & II
- FIR systems: direct-form

LTIS described by constant-coefficient difference equations

- FIR systems
- IIR systems: solution of linear constant-coefficient difference equations
- Impulse response & stability of LTIS

Digital Signal Processing - Summary

The z-transform

- Definition & region of convergence
- Common z-transform pairs
- Rational z-transform
  - Poles & zeros
  - System/transfer function of LTIS
  - Conversion from difference equations
- Inversion of the z-transform
  - Direct evaluation, power series expansion & partial fraction expansion
- Unilateral z-transform
- Analysis of LTIS in z-domain
  - Transient & steady-state response
  - Causality & stability: Schür-Cohn stability test

Digital Signal Processing - Summary

Frequency analysis of discrete-time signals and systems

- Fourier series for discrete-time periodic signals
- Fourier transform for discrete-time aperiodic signals
  - Definition, Relationship with *z*–transform & properties
- Frequency-domain characteristics of LTIS
  - Frequency response function

Discrete Fourier Transform

- Definition, properties & remarks

Digital Signal Processing - Summary

Fast Fourier Transform

- Radix-2 algorithm: decimation-in-time & decimation-in-frequency
- FFT split-radix algorithms

LTIS as frequency selective filters

- Filter design through pole–zero placement
  - LPF, HPF & BPF
- Digital resonators, notch, comb & all-pass filters

Linear-phase FIR filters

Digital Signal Processing - Summary

Design of digital filters

- General considerations
  - Filter specifications
  - Filter approximation
    - Causality and its implications
- Design of digital linear-phase FIR filters
  - Windowing & frequency sampling methods
- Design of digital IIR filters
  - Characteristics of practical frequency selective filters
  - Indirect design methods
    - Impulse invariance, matched-*z* transformation, approximation of derivatives & bilinear transformation
  - Frequency transformations
  - Direct design methods: Padé approximation

Digital Signal Processing - Summary

Structures for realizing discrete-time systems

- FIR systems
  - Direct-form, cascade & lattice structure
- IIR systems
  - Direct-forms I & II, cascade, parallel, lattice & lattice-ladder structures

Outline

Digital Signal Processing Summary

Exam Example

Exam Example (February 2023)

P1 (2.8p) Using FFT radix-2 algorithm: decimation-in-time, evaluate the 8-point DFT of the sequence

$$x(n) = \sin\frac{\pi n}{2}, \qquad n = \overline{0,7}$$

Sketch the magnitude and the phase spectra.

P2 (4.2p) For the causal system described by the transfer function

$$H(z) = \frac{2\left(z^{-1} - \frac{1}{4}z^{-2}\right)\left(1 - \frac{1}{2}z^{-2}\right)}{\left(1 - \frac{1}{2}z^{-1} + \frac{1}{8}z^{-2}\right)\left(1 - \frac{1}{2}z^{-1}\right)}$$

a) 0.7p Draw the pole-zero diagram.

b) 0.5p Write the input-output relationship.

c) 2.0p Sketch the parallel implementation.

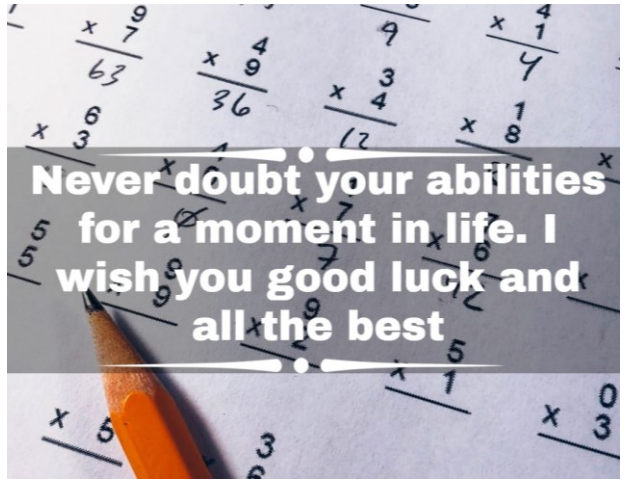
d) 1.0p Evaluate the impulse response sequence (real-valued terms) and specify the ROC of the transfer function.

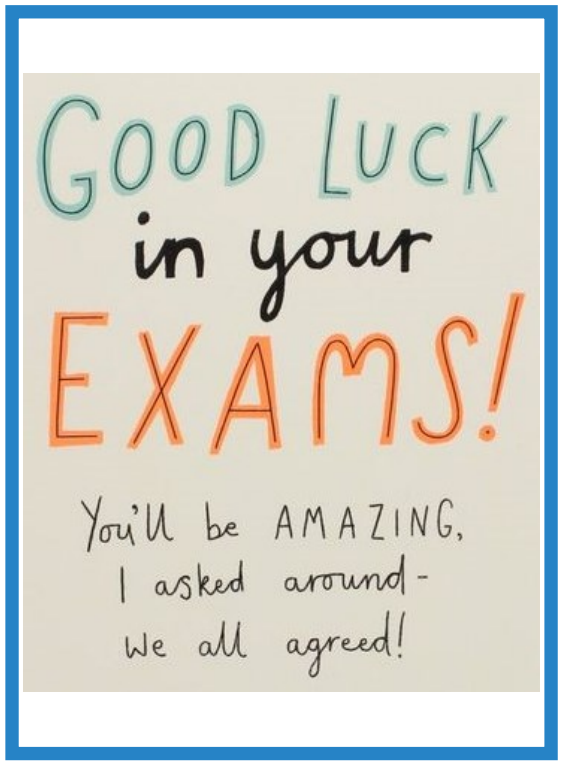
P3 (2.0p) Consider a causal system described by the constant coefficient difference equation.

$$y(n) - \frac{10}{3}y(n-1) + y(n-2) = x(n) + x(n-1)$$

a) 1.5p Determine the unit step response.

b) 0.5p Evaluate the stability of the system.





Examination is the best platform for building up your future. So, take it seriously and give it a hard push. I hope you can do good.

An exam is not only a test of your academic knowledge, but also a test of your calmness, stability and courage.