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 & nonrecursive 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
- 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 & bilinear transformation
  - Frequency transformations

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

Quantization

- A simple DSP system
- Quantization and coding
  - Analysis of quantization errors
  - Statistical model of input quantization error
  - Quantizer SQNR analysis
  - Quantization model of digital filtering

Outline

Digital Signal Processing Summary

Exam Example

Exam Example (June 2023)

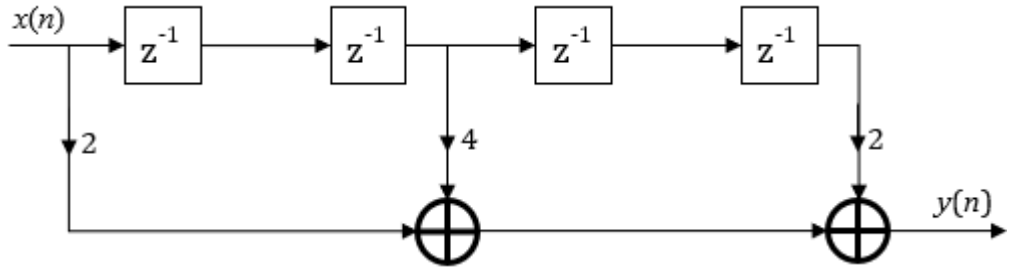
P1 (3p) Consider the discrete-time signal

$$x(n) = \sin\frac{3\pi n}{8}, n = \overline{0,255}$$

a) 1.5p Evaluate the 256-point DFT of the sequence $x(n)$.

b) 1.5p Sketch the magnitude and the phase spectra.

P2 (3p) Consider the FIR filter described by the next block diagram. Determine the first five samples of the causal output sequence, when at the input of the filter $x(n) = 5\exp\left(j\frac{\pi n}{2}\right)u(n)$ is applied. Let $y(-1) = y(-2) = y(-3) = y(-4) = 0$.

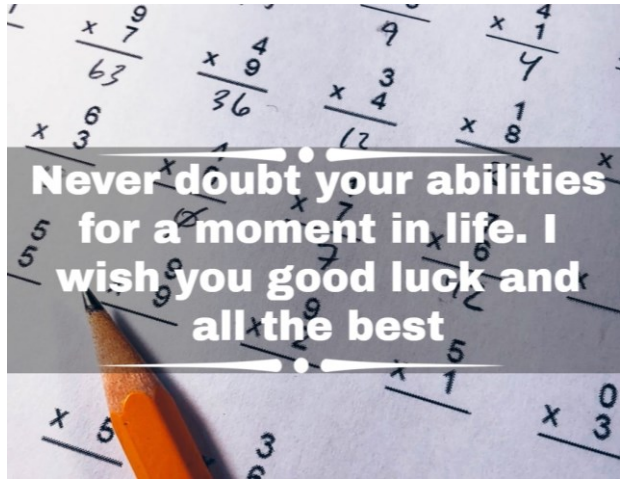


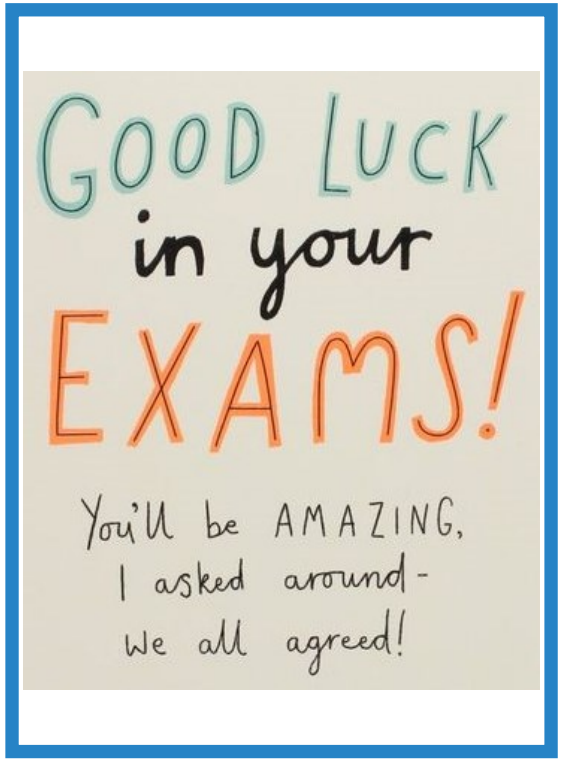
P3 (3p)

a) 2.5p Sketch the lattice-ladder structure corresponding to the filter described by the transfer function.

$$H(z) = \frac{1 + z^{-1} + z^{-2}}{1 - \frac{5}{18}z^{-1} - \frac{7}{18}z^{-2} + \frac{1}{3}z^{-3}}$$

a) 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.