Final Exam Topics

1) Discrete-Time Signals: Sequence
   - Memoryless, LTI, Causality, BIBO Stability
   - Properties of LTI
   - Linear difference equations
   - Eigenfunctions for LTI Systems
   - Transform domain representation: DTFT
   - Properties of the DTFT: linearity, Time/Frequency shifting, time reversal, differentiation in frequency, Parseval's theorem, convolution theorem, modulation/windowing theorem
   - Symmetry properties of DTFT
   - Common DTFT pairs
2) z-Transform
   - Region of convergence
   - Common z-transform pairs
   - Properties of ROC for the z-transform
   - Pole location and time-domain behavior for causal signals
   - Inverse z-transform
     - table lookup or inspection
     - partial fraction expansion
     - power series expansion
   - z-transform properties: linearity, time shifting, multiplication by an exponential sequence, differentiation, conjugation of a complex sequence, time reversal, convolution, initial value theorem, final value theorem
   - Solving linear difference equations
3) Sampling of Continuous-Time Signals
   - Periodic sampling
   - Frequency-domain representation of sampling
     - Nyquist sampling theorem: $\Omega_s \geq 2\Omega_N$
   - Reconstruction of bandlimited signal from its samples
   - Discrete-time processing of continuous-time signals
   - Continuous-time processing of discrete-time signals
   - Change of sampling rate using discrete-time processing
     - Integer factor
     - Non-integer factor
   - Digital processing of analog signal
4) Transform Analysis of LTI Systems
   - Frequency response LTI systems
     - Magnitude, phase, and group delay
   - System functions for systems characterized by linear constant-coefficient difference equations
   - Frequency response for rational system functions
     - single zero or pole
     - second-order IIR
     - second-order FIR
   - Relationship between magnitude and phase
     - If $H(z)$ is causal and stable, then all its poles are inside the unit circle
   - Allpass systems
     - phase of allpass systems is non-positive for $0 \leq \omega < \pi$

- Poles and zeros form conjugate reciprocal pair
- Minimum phase system
  - system factorization: $H(z) = H_{min}(z)H_{ap}(z)$
  - stable and causal inverse systems
  - minimum phase lag, minimum group delay, minimum energy-delay properties
  - maximum phase system - all zeros outside the unit circle
- Generalized linear phase
  - symmetry: even and odd order
  - antisymmetry: even and odd order
- Causal generalized linear phase FIR systems
  - even order: $H\left(e^{j\omega}\right) = A_e\left(e^{j\omega}\right)e^{\frac{-j\omega M}{2}}$, $A_e\left(e^{j\omega}\right)$ is even and real
  - odd order: $H\left(e^{j\omega}\right) = A_o\left(e^{j\omega}\right)e^{\frac{-j\omega M+j\pi}{2}}$, $A_o\left(e^{j\omega}\right)$ is odd and real
  - Type I - IV systems
  - zeros form reciprocal pair: $z_0 = re^{j\theta} \Longrightarrow z_0^{-1} = r^{-1}e^{-j\theta}$
  - for real $h[n]$, zeros come in conjugate pairs: $z_0^* = re^{-j\theta} \Longrightarrow (z_0^*)^{-1} = r^{-1}e^{j\theta}$
- Linear system factorization: $H_{linp}(z) = H_{min}(z)H_{uc}(z)H_{max}(z)$

5) Structures For Discrete-Time Systems
- Basic Structures for IIR Systems
  - Direct Form I and II
  - Cascade Form
  - Parallel Form
- Transpose Form
- Basic Structure for FIR Systems
  - Direct Form
  - Cascade Form
- Linear Phase FIR Systems
  - Type I, II, III and IV
- Effects of Coefficient Quantization
  - effect of poles/zeros location
  - reducing quantization effect by using cascade and parallel structures

6) Filter Design Techniques
- Analog design techniques for IIR filter design
  - Butterworth, Chebyshev I and II, Elliptic
    - impulse Invariance
    - bilinear Transform
- FIR filter design using windowing techniques
  - Rectangular (boxcar), Barlett (triangular), Hanning, Hamming, Blackman
  - Kaiser
    - trade-off between mainlobe width and sidelobe attenuation
  - optimization technique
    - least-squares criterion
    - minimax criterion
    - Least-squares filter design
    - Filter design via linear programming
- comparison between IIR and FIR filters

7) Discrete Fourier Transform
- Discrete Fourier Series (DFS)
  - Sampling of the unit circle

- DFT
  - properties of DFS and DFT
- circular convolution
- linear convolution using DFT
- block convolution
  - overlap-add
  - overlap-save
    - vector-matrix equation
    - interblock interference
    - diagonalization of circulant matrices

8) Computation of the DFT: Fast Fourier Transform (FFT)
   - Decimation-in-time (radix-2)
   - Decimation-in-frequency (radix-2)
   - in-place computation, storage, access
   - Cooley-Tukey algorithm (Composite N algorithm)
   - inverse DFT