Exam 1

Topics

- Representations
    - System functional/Transfer function (product of factors vs. partial fraction forms)
    - Difference equations
    - DT signal as a (possibly infinite) sum of R^n terms
    - DT signal as a weighted sum of modes (p^n)
    - DT signals as a plot or list of values
    - Block diagram (cascades, feedback/feed-forward sums)
    - Pole diagram (root locus)
- Poles and modes of a system, including such topics as
    - Characteristics of real vs. imaginary poles in the time domain
    - Constraints on imaginary poles
    - Convergent, divergent, and perpetual modes; oscillatory vs. non-oscillatory modes; pole characteristics that lead to all possible combinations
    - Modes related to double/triple poles
    - Complex number representations
        - Real and imaginary parts
        - Polar form
        - Pairs of complex numbers as sines or cosines
- Sample function and impulse response, including
    - Definitions
    - Relation between the impulse response and the system functional
    - Relation to modes and poles
- Outputs given arbitrary inputs and how the form of the output relates to modes and poles
- Partial fractions and when to use them

Useful Skills (This is not an exhaustive list. It simply gives highlights a few skills to give you a flavor of what you should know how to do.)

- Translating between any combination of the representations or representational forms listed above.
- Given a system functional, difference equation, or block diagram
    - Determining the output for any simple input (e.g., a step function or signal with only a few non-zero samples)
    - Determining the impulse response
    - Determining the poles/modes
- Translating complex poles
    - From real-imaginary form to polar form and vice versa
    - Pairs of poles into sines and cosines and vice versa

Exam 2

Topics

- Differential Equations, the impulse response as a particular solution, the relationship between poles and the form of the homogeneous solution
- Laplace transform definition and topics like
    - Properties of Laplace transforms (esp. integration, differentiation, and convolution)
    - Common transforms and how they vary based on the ROC (esp. delta functions, one pole transforms, transforms with two distinct poles, repeated pole transforms)
    - Region of convergence – what is it and how does it affect inverse transforms
    - Stability, causality, anti-causality, two-sidedness and what they mean in the transform domain (ROC) and the time domain
- Z transform definition and topics like
    - Properties of Z transforms (esp. left shifts, right shifts, and convolution)
    - Common transforms and how they vary based on the ROC (esp. delta functions, one pole transforms, transforms with two distinct poles, repeated pole transforms)
    - Region of convergence – what it is and how it affects inverse transforms
    - Stability, causality, anti-causality, two-sidedness and what they mean in the transform domain (ROC) and the time domain
    - The correspondence between these topics and topics covered during the first part of the class
- Relationship between the impulse response and the transfer function
- CT Block diagrams using the A operator; LT equivalent of the A operator
- Eigenfunctions in CT and DT
- Delta functions and step functions; unique properties and definitions; integrating over a delta
- Convolution
    - Effect of convolving with unit-sample or delta functions, step functions, rectangle functions
    - Two methods for performing DT convolution
        - Flip and shift
        - Generating a shifted impulse response for each sample of the input, then adding
    - CT convolution
        - Flip and shift method
        - Geometric methods for reasoning about the convolution integral as area under a curve

Useful Skills (This is not an exhaustive list. It simply gives highlights a few skills to give you a flavor of what you should know how to do.)

- Performing simple CT convolutions
    - CT convolutions with boxes, triangles, and simple finite-duration signals
    - Visually recognizing when the convolution integral involves area cancellations
    - Using differentiation, integration, or Laplace transforms to simplify calculations
- Given the input of a system, finding the output via convolution, transforms, or eigenfunction relationships (or vice versa)
- Taking Laplace and Z-transforms using properties, common transforms, and transform definitions
- Identifying poles and regions of convergence
- Finding transforms and inverse transforms for casual, anti-causal, and two-sided signals
- Using the ROC to determine causality, stability, anti-causality, and two-sidedness; Recognizing these properties in time domain signals
- Working with the transform definitions
- Converting between difference/differential equations, transforms, and block diagrams

Exam 3

Topics

- Second order systems
    - Output of a system in terms of H(jw) when the system receives a sinusoid as an input
    - Root locus movement of the poles in terms of Q, how the response varies based on pole location, definition of high-Q systems
    - Relationship between rate at which the amplitude of the impulse response decays, the width and height of the 3dB peak in the magnitude plot, and the change in phase over the 3dB bandwidth for high-Q systems
- Bode plots (to be complete, a Bode plot must include both a magnitude plot and a phase plot)
    - Effects of poles and zeros in both the left and right half planes
    - Line-approximations for magnitude and phase plots
    - Conditions under which line-approximations break down
    - Relationship between Bode plots and a system's response to sinusoidal inputs
    - 3dB bandwidth
- Definitions for periodic functions, even/odd functions
- Fourier series definition and topics like
    - Transform and synthesis equation
    - Properties (esp., DC component, even/odd symmetry, time-shifting, differentiation, integration, scaling)
    - Common transforms (e.g., sinusoids, impulse trains)
    - Gibbs phenomenon
- Fourier transform
    - Transform and synthesis equation
    - Translating from FS to FT (using delta functions)
    - Relationship between the LT and FT, ROC conditions for the FT to exist
    - Properties (esp., convolution/multiplication, integration, differentiation, even/odd symmetry, shifting, scaling)
    - Common transforms (esp., boxes and sincs, deltas and complex exponentials, string of deltas)
    - Parseval's equation
    - Duality

Useful Skills (This is not an exhaustive list. It simply gives highlights a few skills to give you a flavor of what you should know how to do.)

- Identify the decay rate and oscillation period from the impulse response of a second order system and relate it to the poles of the system
- Draw the straight-line Bode plot (magnitude and phase) for a rational system function
- Infer pole and zero locations from a Bode plot
- Determine the response of a system to a sinusoidal input using its Bode plot
- Find the FS/FT of simple signals (boxes, sincs, complex exponentials, real sinusoids, impulses)
- Use FS/FT properties to efficiently determine the FS/FT of signals derived from simpler signals
- Convert between FS and FT representations of a periodic signal
- Determine the Fourier representation (series or transform) of an input signal, determine the frequency response of a system, and then compute the output based on these frequency-domain representations (notion of filtering)

Topics since Exam 3

- Discrete-Time Fourier Series (DTFS) and Discrete-Time Fourier Transform (DTFT)
    - Eigenfunction for discrete time LTI system is z^n,
    - DT frequency response is evaluated along unit circle, $z = e^{j\Omega}$
    - Periodicity of DT freq responses: DTFS and DTFT are *always periodic with 2π*!
    - Discrete-Time Fourier Series: harmonics interpretation, analysis and synthesis are over a period of N
    - Properties of DTFS and DTFT, and how they are similar to properties of previously discussed Fourier representations
- Relationships among Fourier Representations
    - Periodic signal → Expect transform to be "discrete" (i.e. FS or FT with impulses)
        - Convert between FS and FT representations
        - Convolving with impulse train in time (extending periodically) → Multiplication with an impulse train in frequency
    - Discrete signal → Expect transform to be "periodic" (replicated) in frequency
        - Multiplication with an impulse train in time ("sampling") → Convolution with an impulse train in frequency
        - CTFT of "sampled" signal $x_p(t)$ has same shape as DTFT of x[n]
- Sampling
    - Analyze effect of sampling using CTFT notation in frequency domain
        - Relate sampled signal $x_p(t) <=> X_p(j\omega)$ to $x_d[n] <=> X_d(e^{j\Omega})$
        - $\Omega = \omega T$
    - Nyquist sampling theorem (Nyquist rate) and when aliasing occurs
        - *Aliasing = New frequencies may be created = System may not be LTI*
    - Anti-aliasing filter
- Modulation
    - Amplitude modulation, what it looks like in the time and frequency domains, and how to recover a signal (demodulation)
    - Phase modulation (microscopy demo)
    - Familiarity with frequency modulation (FM), hard to analyze in Fourier domain

Useful skills (This is not an exhaustive list. It simply highlights a few skills to give you a flavor of what you should know how to do.)

- Use moments of various transforms to check your work. For instance, X(j0) is the average value of x(t). Similarly, a_0 in FS is the average value of x(t) over a period.
- Be able to convert between and do *filtering* on various Fourier representations.
- Use diagrams and impulse trains to understand impulse sampling and reconstruction, as well as other variants of sampling.
- DT processing of CT signals: Determine the overall continuous $H(j\omega)$ for the system, and be able to tell if a system is LTI.
- Identifying when aliasing occurs and what the affects of aliasing are in both the time and frequency domains