Course Number: ECE 601

Course Name: Linear Systems

Prerequisites: An undergraduate course in Signals and Systems

Course Description: Analytical methods are developed for studying the behavior of continuous-time and discrete-time linear systems. Input-Output (external) representation of systems as well as internal (state-space) representation are analyzed. Frequency domain as well as time-domain methods are used. Among the properties of systems to be discussed are controllability, observability and stability.

Many schools present the subject of Linear Systems as two separate courses, one in which the system is analyzed within frequency domain methods and the other within state-space methods. As described above this course contains both methods in a single course. At NJIT, the course is a 3-hr-per-week course rather than the more conventional 2-hr-per-week course in most schools.

Textbook: Since this course covers material usually presented in two courses, there is no single textbook that adequately covers both subjects.(frequency domain and state-space), although there are many textbooks that cover the individual material. As a result, a set of handwritten notes was especially developed for this course. It is the official textbook for the course and consists of two volumes of notes entitled "Linear Systems ECE 601 Volume 1 & Volume 2 by Richman which are available at the NJIT bookstore

Optional textbooks (not required) are
 "Linear Systems and Signals" By B.P Lathi – Oxford University Press 2005 (covers the material for the first half of course)
"Principles of Linear Systems" By P. Sarachik – Canbridge University Press 1997 (covers the material for the second half of the course)

Grading Schema: Final grade for the course will be based on the average of Midterm and Final exams. Completion of homework assignments will account for an improvement in final grade by a half-grade (e.g., from B to B+)

Academic Integrity Policy: The NJIT Honor Code will be upheld, any violations will be brought to the immediate attention of the Dean of Students

ECE 601 Syllabus: The following 10 topics will be covered. Most topics will be covered in 1 lecture while a few will be covered in 1 ½ to 2 lectures

1. **Introduction To Linear System Analysis**
   - Definition of a System
   - Simple Examples
   - The General Problem
   - The Two Different Approaches For Analyzing Systems
   - Basic Concepts, Terms and Definitions
     o Input-Output Relations
     o Linearity
     o Time-Invariance
     o Causality

2. **Time-Domain Analysis of Input-Output Representation**
   A. Continuous-Time Systems
   - Elementary Functions
   - Distribution Theory
   - Resolution of Arbitrary Signals
   - Impulse and Step Response
   - Convolution Integrals

   B. Discrete-Time Systems
   - Discrete-Time Impulse Function (Kronecker Delta Function)
   - Discrete-Time Impulse Response
   - Discrete-Time Convolution Sum and Solution

3. **Frequency Domain Analysis of Continuous-Time Systems**
   - Fourier Series (for obtaining properties of signals)
     o Properties of Fourier Series
     o Signal Spectra
   - Fourier Transforms (for obtaining properties of systems)
     o Properties of Fourier Transforms
     o System Response Function and its Spectra
     o Fourier Series Coefficients From Fourier Transform
   - Laplace Transforms
     o Easier to Use Than Fourier Transforms
     o Limitations of Laplace Transforms
     o Properties of Laplace Transforms
     o Relationship to Fourier Transforms

4. Frequency Domain Analysis of Discrete-Time Systems
- Discrete-Time Fourier Series (for obtaining properties of sampled signals)
  - Properties of Discrete-Time Fourier Series
  - Discrete-Time Signal Spectra
  - Aliasing

- Discrete-Time Fourier Transform
  - Properties of Discrete-Time Fourier Transforms
  - Discrete-Time Response Function and its Spectra
  - Discrete-Time Fourier Series Coefficients From Fourier Transform

- Z-Transforms
  - Discrete-Time Counterpart of Laplace Transforms
  - Easier to Use Than Fourier Transforms
  - Properties of Z-Transforms
  - Relationship to Discrete-Time Fourier Transforms

5. State Variable Representation of Continuous-Time Systems
- Definition of State Vector
- Review of Matrix Algebra
- Representation in State-Variable form
  - Companion Forms
  - Jordan Form
  - Similarity Transformations
  - Use of Software (MATLAB)

6. Solution of the Continuous-Time State Equations
- The State Transition matrix
  - Properties
  - Method of Finding
- The Complete Solution

7. Solution of the Discrete-Time State Equations
- The Discrete-Time Transition matrix
  - Properties
  - Method of Finding
- The Complete Solution

8. Methods for Discretizing Continuous-Time Systems
- Sample and Zero-Order Hold
- Bilinear Transformation

9. Controllability and Observability of Linear Systems
- Definitions
- Examples of How Unwanted Uncontrollable and Unobservable Systems Can Arise
- The General Controllability Theorem (difficult to use)
- The Algebraic Controllability Theorem for time-invariant systems (easier to use)
- The General Observability Theorem (difficult to use)
- The Algebraic Observability Theorem for time-invariant systems (easier to use)

10. Stability of Linear Systems
- Continuous-Time Systems
  - Definitions
  - Bounded-Input-Bounded-Output (BIBO) Stability
  - Internal Stability

- Discrete-Time Systems
  - Definitions
  - Bounded-Input-Bounded-Output (BIBO) Stability
  - Internal Stability