# Department of Electrical Engineering,
# School of Engineering,
# University of Management and Technology

## Course Outline

**Course code……EE 360… Course title……Control Systems…**

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| Program | BSEE |
| Credit Hours | 3 |
| Duration | One semester |
| Prerequisites | EE315:Signals and Systems<br>MA-230:Differential Equations |
| Resource Person (s) | Jameel Ahmad, M Ilyas Khan |
| Counseling Timing | Contact Respective Teacher in SEN building |
| Contacts | Jameel Ahmad Jameel.ahmad@umt.edu.pk (0333-558-3815)<br>M Ilyas Khan Ilyas.khan@umt.edu.pk |

**Chairman/Director signature………………………………….**

**Dean's signature……………………………**

**Date………………………………………….**

## Course Description

The course deals with the analysis and design of linear feedback control systems. Feedback systems are ubiquitous in daily life and appear in many disciplines including communications, industrial processes, aerospace systems, vehicle engine systems and elsewhere. Classical control methods of analysis and design are used for linear systems and provide intuitive procedures for feedback control based on systems structure. State Variable methods have been responsible for the high performance and stability of modern engineered systems including aerospace, robotic, and industrial processes with many inputs and many outputs (MIMO). Mathematical modeling of different electro-mechanical control systems through transfer function and state space models will be studied exhaustively. Transient and steady state analysis will be introduced. Root-locus analysis and design method will be studied for PI, PD, PID, and Lead-Lag controllers. Students will be able to analyze frequency response via Phase and Gain Margin of Control systems using Bode plots.

## Course Learning Objectives:

Specific Course objectives are as follows:-

1. To provide students with basic background in Linear Feedback Control Systems analysis and design.
2. To lay the foundations of classical control design including Root locus, Frequency Response via Bode Plots, stability analysis.
3. To understand tools for system analysis including differential equations, transfer functions, and state variable methods.
4. To provide an introduction to basic analysis and design methods in state variable systems.
5. To train students in the use of the Control System Toolbox, Simulink®, the Symbolic Math Toolbox, and MATLAB®'s graphical user interface (GUI) tools for system design and simulation for the workplace.
6. The lab sections will give students an understanding of implementing these concepts on actual physical processes including DC motor Speed Control, Magnetic Levitation, Ball and Beam system, Inverted Pendulum, Servo mechanisms.

## Course Learning Outcomes:

1. Acquire the mathematical tools needed to analyze feedback control systems by classical methods including Root locus, Bode, and Routh Stability Test.
2. Students will learn about stability of open-loop and closed-loop systems.
3. Understand the basic concepts of state variable analysis.
4. Ability to perform designs with various control tools using MATLAB computer simulation toolboxes.
5. Understand the implementation of feedback control systems methods on actual industrial processes and case studies.
6. Learn to work in teams and contribute as a member to a group project.

## Learning Methodology:

Lecture, interactive, participative, Computer Simulations

## Grade Evaluation Criteria

Following is the criteria for the distribution of marks to evaluate final grade in a semester.

| Marks Evaluation | Marks in percentage |
|---|---|
| Quizzes and Assignments | 25 |
| Midterm Exam | 25 |
| Attendance & Class Participation | NA |
| Term Project | NA |
| Presentations | NA |
| Final exam | 50 |
| Total | 100 |

**Required Textbook:**

1. **Control Systems Engineering** by Norman S. Nise, 6th /7th edition (2015)

**Reference Books:**

2. **Modern Control Engineering** (5th Edition) by Katsuhiko Ogata (Sep 4, 2009)
3. **Analog and Digital Control System Design: Transfer-Function, State-Space, and Algebraic Methods** by Chi-Tsong Chen (Jan 1, 1993)
4. **Modern Control Systems** (12th Edition) by Richard C. Dorf and Robert H. Bishop (Jul 29, 2010)
5. **State Variables for Engineers** by Paul M. DeRusso, Rob J. Roy, Charles M. Close and Alan A. Desrochers (Dec 1997)
6. **Control System Design: An Introduction to State-**Space ,Bernard Friedland (Mar 24, 2005)

# Calendar of Course contents to be covered during semester

**Course code……………..EE360 Course title……Control Systems**

| Lecture (Lx) | Lecture Contents and Chapter Sections | Reference Chapter(s) |
|---|---|---|
| **After lectures L1&L2 student will be able to**<br>1. Define a control system and describe some applications (Section 1.1)<br>2. Describe historical developments leading to modern day control theory (Section 1.2)<br>3. Describe the basic features and configurations of control systems (Section 1.3)<br>4. Describe control systems analysis and design objectives (Section 1.4)<br>5. Describe a control system's design process (Sections 1.5–1.6) | | **Chapter 1** **Learning Outcome** |
| L1 | 1.1 Define control system<br>1.2 History of control systems<br>1.3 Basic features and configurations of control systems | **[1]Chapter 1** **Introduction** |
| L2 | 1.4 Describe control systems analysis and design objectives<br>1.5 Describe a control system's design process<br>1.5 Computer Aided Design | |
| **After lectures L3-L6 student will be able to**<br>1. Find the Laplace transform of time functions and the inverse Laplace transform (Sections 2.1–2.2)<br>2. Find the transfer function from a differential equation and solve the differential equation using the transfer function (Section 2.3)<br>3. Find the transfer function for linear, time-invariant electrical networks (Section 2.4)<br>4. Find the transfer function for linear, time-invariant translational mechanical systems (Section 2.5)<br>5. Find the transfer function for linear, time-invariant electromechanical systems (Section 2.8)<br>6. Linearize a nonlinear system in order to find the transfer function (Sections 2.10–2.11) | | **Chapter 2** **Learning outcome** |
| L3 | 2.1-2.2 Laplace Transform and its inverse | **[1]Chapter 2** |

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| | 2.3 Transfer Function and differential equations<br>2.4 Electrical Network Transfer Function<br>Quiz-1 will be conducted<br>Homework-1 will be given + Case study-1 from Book | **Modeling in Frequency Domain** |
| L4 | 2.5 Transfer function for translational mechanical system | |
| L5 | 2.8 Transfer function for electro-mechanical system | |
| L6 | 2.11 Transfer function for non-linear systems and its linearization<br>Quiz-2 will be conducted based on HW1 | |
| **After lectures L7-L10 student will be able to**<br>1. Find a mathematical model, called a state-space representation, for a linear, time invariant system (Sections 3.1–3.3)<br>2. Model electrical and mechanical systems in state space (Section 3.4)<br>3. Convert a transfer function to state space (Section 3.5)<br>4. Convert a state-space representation to a transfer function (Section 3.6)<br>5. Linearize a state-space representation (Section 3.7) | | **Chapter-3 Learning Outcome** |
| L7 | 3.1-3.3 State Space Model: A general Representation<br>Homework-2 will be given + Case study-2 from Book | **[1] Chapter 3 Modeling in Time domain** |
| L8 | 3.4 Model Electrical and Mechanical System in Sate-Space | |
| L9 | 3.5-3.6 Convert A transfer function into state space and vice versa, Phase variable form<br>Quiz-3 will be conducted based on HW-1 and HW-2 | |
| L10 | 3.7 Linearize state space representation<br>Homework-3 will be given + Case study-3 from Book | |
| **After lectures L11-L14 student will be able to**<br>1. Use poles and zeros of transfer functions to determine the time response of a control system (Sections 4.1–4.2)<br>2. Describe quantitatively the transient response of first-order systems (Section 4.3)<br>3. Write the general response of second-order systems given the pole location (Section 4.4)<br>4. Find the damping ratio and natural frequency of a second-order system (Section 4.5)<br>5. Find the settling time, peak time, percent overshoot, and rise time for an underdamped second-order system (Section 4.6)<br>6. Describe the effects of nonlinearities on the system time response (Section 4.9)<br>7. Find the time response from the state-space representation (Sections 4.10–4.11) | | **Chapter-4 Learning outcome** |
| L11 | 4.1-4.4 Time response of first order and $2^{nd}$ order systems | **[1] Chapter 4 Time Response** |
| L12 | 4.5-4.6 Time Response of second and higher order systems with additional poles and zeroes | |
| L13 | 4.9 effects of nonlinearities on the system time response<br>Quiz-4 will be conducted based on HW-3 | |
| L14 | 4.10-4.11 the time response from the state-space representation | |
| L15-L16 | **Midterm** | |
| **After lectures L17 student will be able to**<br>1. Reduce a block diagram of multiple subsystems to a single block representing the transfer function from input to output (Sections 5.1–5.2) | | **Chapter 5 Learning Outcome** |

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| L17 | 5.1-5.3 Reduction of Block Diagrams of multiple sub systems to a single control loop, signal flow graphs | **[1] Chapter 5**<br>**Reduction of Multiple subsystems** |
| **After lectures L18-L19 student will be able to**<br>1. Make and interpret a basic Routh table to determine the stability of a system (Sections 6.1–6.2)<br>2. Make and interpret a Routh table where either the first element of a row is zero or an entire row is zero (Sections 6.3–6.4)<br>3. Use a Routh table to determine the stability of a system represented in state space (Section 6.5) | | **Chapter 6**<br>**Learning Outcome** |
| L18 | 6.1-6.2 Routh Stability-1<br>Homework-4 will be given + Case study-4 from Book | **[1] Chapter 6**<br>**Stability** |
| L19 | 6.3-6.5 Routh Stability-2 | |
| **After lectures L20-L21 student will be able to**<br>1. Find the steady-state error for a unity feedback system (Sections 7.1–7.2)<br>2. Specify a system's steady-state error performance (Section 7.3)<br>3. Design the gain of a closed-loop system to meet a steady-state error specification (Section 7.4) | | |
| L20 | 7.1-7.2 Steady-State Error for Unity Feedback Systems<br>Quiz-5 will be conducted based on HW-4 | **[1] Chapter 7**<br>**Steady State Errors** |
| L21 | 7.3 Static Error Constants and System Type | |
| **After lectures L22-L24 student will be able to**<br>1. Define a root locus (Sections 8.1–8.2)<br>2. State the properties of a root locus (Section 8.3)<br>3. Sketch a root locus (Section 8.4)<br>4. Find the coordinates of points on the root locus and their associated gains<br>5. (Sections 8.5–8.6)<br>6. Use the root locus to design a parameter value to meet a transient response specification for systems of order 2 and higher (Sections 8.7–8.8) | | **Chapter 8**<br>**Learning Outcome** |
| L22 | 8.1-8.3 Root Locus Technique-1<br>Homework-5 will be given + Case study-5 from Book | **[1] Chapter 8**<br>**Root Locus Technique** |
| L23 | 8.4-8.6 Sketching Root Locus and associated gains | |
| L24 | 8.7-8.8 Parameter design for specific Transient Response<br>Quiz-6 will be conducted based on HW-5 | |
| **After lectures L25-L27 student will be able to**<br>1. Use the root locus to design cascade compensators to improve the steady-state error (Sections 9.1–9.2)<br>2. Use the root locus to design cascade compensators to improve the transient response (Section 9.3)<br>3. Use the root locus to design cascade compensators to improve both the steady-state error and the transient response (Section 9.4)<br>4. Realize the designed compensators physically (Section 9.6) | | **Chapter 9**<br>**Learning Outcome** |
| L25 | 9.1-9.2 Use the root locus to design cascade compensators to improve the steady-state error : PI control and Lag Compensator | **[1] Chapter 9** |

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| | Homework-6 will be given + Case study-6 from Book | **Design Via Root Locus** |
| L26 | 9.3 Use the root locus to design cascade compensators to improve the transient response : PD and Lead Compensation<br>9.6 Realization of Compensators Physically-Op-Amp based Circuits | |
| L27 | 9.4 Improving steady-state and transient response: PID Control/lead-Lag compensator<br>Quiz-7 will be conducted based on HW-6 | |
| **After lectures L28-L30 student will be able to**<br>1. Define and plot the frequency response of a system (Section 10.1)<br>2. Plot asymptotic approximations to the frequency response of a system (Section 10.2)<br>3. Find stability, gain and phase margins using Bode plots (Sections 10.7) | | **Chapter 10 Learning Outcome** |
| L28 | 10.1 Plot Frequency Response of the system<br>Homework-6 will be given + Case study-6 from Book | **[1] Chapter 10 Frequency Response Technique** |
| L29 | 10.2 Plot asymptotic approximations to the frequency response of a system: Bode Plots | |
| L30 | 10.7 Find stability, gain and phase margins using Bode plots<br>Quiz-8 will be conducted based on HW-7 | |
| L31-L32 | **Final Examination** | |
| **End of Semester** | | |