# BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI HYDERABAD CAMPUS

**SECOND SEMESTER 2021-2022**

**COURSE HANDOUT (PART II)**

Date:15/01/22

In addition to part-I (General Handout for all courses appended to the timetable) this portion gives further specific details regarding the course.

# Course No. : ECE F242, EEE F242, INSTR F242

**Course Title : Control Systems Instructor-in-charge : Dr. Pratyush Chakraborty**

**Instructors : Prof. Alivelu Manga Parimi , Dr Ankur Bhattacharjee, Dr. Joyjit Mukherjee**

1. **Scope & Objective of the Course:**

Feedback automatic control systems are an essential feature of numerous industrial processes, scientific instruments and even commercial, social and management situations. A thorough understanding of the elementary principles of this all embracing technology is of great relevance for all engineers and scientists. This course tries to bring out the basic principles of Feedback Control Systems.

# Learning outcomes:

By the end of the semester, the students should be able to:

* + Develop mathematical models of linear time invariant (LTI) control systems for electrical, mechanical and electromechanical systems.
  + Analyze the transient response, steady-state response and system stability of LTI control system.
  + Analyze and design control system compensators to achieve specified control system performances in time domain utilizing root-locus techniques.
  + Analyze and design control system compensators to achieve specified control system performances utilizing frequency-response techniques.

# Text Book:

**(T1)** Nagrath I. J. and M. Gopal, Control Systems Engineering, New Age International (P) Limited,

**5thed**, 2007.

# Reference Books:

(**R1)** Kuo, B. C., and Golnaraghi, F., Automatic Control Systems, John Wiley & Sons, 8thed, 2003. (**R2)** Dorf, R. C., and Bishop, R. H., Modern Control Systems, Addison Wesley, 7thed, 1995.

(**R3)** Norman S. Nise, Control System Engineering, John Wiley & Sons, 4th ed, 2009.

# Course Plan:

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| **Lecture No.** | **Learning objectives** | **Topics to be covered** | **Chapter in the Text Book** |
| **1** | Introduction  Control system terminology-system, control, feedback, transfer function. Linear Time invariant system | General understanding of the concept of control system. Identification of various examples encountered in life from engineering and non- engineering fields as well. | 1.1-1.4 and Class notes |

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| **2** | Introduction to Laplace transform and its application to control systems | Basics of Laplace transform to derive the transfer function, convert differential equation into transfer function and vice versa. | Class Notes and appendix- I |
| **3** | Mathematical Modelling.  Integro-differential equations for electrical, mechanical systems and Transfer functions, , Gear reduction, disturbance input | Understanding examples from various systems and making block diagram model of the same. Working out transfer function by various methods and gears | 2.1, 2.2 |
| **4** | Mathematical modelling of electromechanical system – example of control of armature and field controlled DC motor as a drive, hydraulic and thermal system examples | Understanding the electromechanical system with DC motor as an example and developing the block diagram | 2.4 |
| **5-6** | Block diagram development, closed loop transfer function | Developing a block diagram of applications | 2.5 |
| **7-8** | Signal flow graph  Mason’s gain formula, Various Examples | Developing the signal flow graph of a system | 2.6, |
| **9** | Open loop and closed loop example.  Effect on gain, dynamic response disturbance input | Learning about more examples of open loop and closed loop control systems and their comparison | 3.1 |
| **10** | Sensitivity to parameter variation.  Concept of frequency content in signals, regenerative feedback, further examples | To learn the control of system sensitive to parameter variations | 3.2, 3.6, 3.7 |
| **11** | Examples of servomotor, stepper motor | linearization concept, block diagram and transfer function of real life examples. | 4.1, 4,2,  4.3,4.4 |
| **12** | Hydraulic control system Pneumatic control components | Block diagram and transfer function development | 4.5, 4.6 |
| **13-14** | Various Test signals in time domain, Response of zeroth and first order systems Second order systems | Transient and natural response analysis of dynamic first order systems to different excitations | 5.1, 5.2, 5.3  5.4 |
| **15-16** | Time response specifications of second order systems, error constants, effect of adding pole(s)/zero(s) | Transient and natural response analysis of dynamic second order systems to different excitations | 5.4, 5,5, 5.6 |
| **17-18** | Compensation Techniques Higher order systems. | To design control system for given time domain specifications. | 5.7, 5.8, 5.10 |
| **19-20** | Stability; Routh criterion | To apply Routh Test to closed loop system stability study. | 6.1, 6.2, 6.4,  6.5, 6.6 |
| **21** | Root Locus. Introduction,  Magnitude and Angle criterion | To draw root locus for various systems and there from infer information on time response and stability | 7.1, 7.2 |
| **22-23** | Root Locus for second order systems without zero and with zeros | - do - | 7.2 |
| **24** | Other rules of root locus. Higher order examples. | - do - | 7.3  7.5 |
| **25** | Higher order examples (contd.) Root contours | - do - | 7.4 |

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| **25-26** | Frequency Response; Introduction, Polar plot | To plot frequency response of systems and use for analysis by frequency domain approach. | 8.1, 8.2, 8.3 |
| **27-28** | Bode plot | - do - | 8.4 |
| **29** | Identification of Transfer function from Bode plot, Gain margin and phase margin | - do - | 8.5 & 8.6,9.4 |
| **30** | Nyquist criterion; Introduction.  Nyquist contour | Investigation of the stability of closed loop system using their open loop transfer function frequency plot. | 9.1, 9.2, 9.3 |
| **31-32** | Nyquist stability criterion. Various Examples | - do - | 9.3 |
| **33-35** | Introduction to Design | To design lag, lead compensators, Tuning of PID controllers | 10.1-10.7 |
| **36-40** | State variable analysis and design | Analysis and design of a system using state variable approach | 12.1 to 12.9 |

1. **Evaluation Scheme:**

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| **Component** | **Duration** | **Weightage** | **Marks** | **Date & Time** | **Nature of Component** |
| Midsem | 1.5 hours | 30% | 90 | 12/03 11.00am to12.30pm | OB |
| Quizzes (3) | 30 min | 30% | 90 | To be announced | OB |
| Comprehensive Exam. | 2 hours | 20% CB,  20% OB | 120 | 11/05 AN | CB, OB |

1. **Chamber Consultation Hours:** to be announced in the class.
2. **Notices:** Notices concerning the course will be put up on the CMS website.
3. **Make-up Policy:** No make up for quizzes and assignments.
4. **Academic Honesty and Integrity Policy:** Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

# Instructor-In-Charge

ECE F242, EEE F242, INSTR F242