Course Type	Course Code	Name of the Course	L	T	P	Credits
DE	NEED512	Multivariable Control and Estimation	3	0	0	3

Course Objectives:

- The ever-increasing complexity of real-time control systems require robust and optimal control and estimation methods. In this course, design of systems in state variable format is covered along with their control. The theory and application of Kalman filters for state estimation is performed. The above-mentioned multivariable control and estimation problems in the real world will be discussed and solved using computer tools. However, strong fundamental knowledge about control system is the prerequisite for the course.

Learning Outcomes:

Upon the completion of the course, students will:

- Understand the control design methods for dynamic systems with noisy inputs
- Implement different digital multivariable control methods for real-world applications
- Understand the importance of state and parameter estimation in stochastic systems.
- Implement various discrete Kalman filtering techniques for precise state estimation.

Unit No	Topics to be covered	Lecture Hours	Learning Outcome
1	**Introduction:** Open and Closed loop systems, Applications, Feedback control systems, Modelling of mechanical/electrical system elements, Time to frequency domain, Transient response and s-plane root locations, Design specifications, Dynamic properties of LTI systems.	7	Introduction to control system applications in various fields and departments, their design perspectives
2	**State-space dynamic system:** Canonical forms for LTI state-space models, MIMO canonical forms, Time (dynamic) response, Zeros of a state-space system, Discrete-time state-space form, Linear time-varying and nonlinear discrete-time systems, Stability of localized liner systems, Input-Output stability, Continuous time and Discrete-time controllability and observability	9	Acquire knowledge on multivariable systems, their representation and MIMO system goals
3	**State-feedback control:** Bass-Gura pole placement, Ackermann's formula, Integral control for continuous-time systems, State feedback for discrete-time systems, MIMO control design.	9	Understand State-feedback control methods
4	**Output-feedback control:** Open-loop and closed-loop estimators, observer gain design problem, Discrete-time prediction estimator, Compensation design- continuous and discrete-time, Separation principle, Discrete-time reduced-order estimator and compensator	9	Understand Output-feedback control methods
5	**Vector random processes:** Scalar random variables, Vector random variables, Uncorrelated versus independent, Functions of random variables, Conditioning, Vector random (stochastic) processes, Discrete-time systems with random inputs, Kalman filter estimation methods	8	Understand random processes and random variables, Application of Kalman filters
	Total Contact Hours	**42**	

Text Books:

1. Simon, D., Optimal State Estimation: Kalman, H∞ and Nonlinear Approaches, Wiley Interscience, 2006.
2. Joao P. Hespanha, Linear Systems Theory, Princeton University Press, 2009.

Reference Books:

1. Jeffrey B. Burl, Linear Optimal Control: H2 and H∞ Methods, Addison-Wesley, Menlo Park, CA, 1999.
2. M. Gopal, Digital control and state variable methods, Tata-McGraw Hill, 2003.