AEEE542 - Linear Systems Analysis

<table>
<tr><td>Course Title</td><td colspan="5">Linear Systems Analysis</td></tr>
<tr><td>Course Code</td><td colspan="5">AEEE542</td></tr>
<tr><td>Course Type</td><td colspan="5">Technical Elective</td></tr>
<tr><td>Level</td><td colspan="5">MSc (Level 2)</td></tr>
<tr><td>Year / Semester</td><td colspan="5">1 or 2</td></tr>
<tr><td>Teacher's Name</td><td colspan="5">Assoc. Prof. Marios Lestas</td></tr>
<tr><td>ECTS</td><td>8</td><td>Lectures / week</td><td>3</td><td>Laboratories/week</td><td>0</td></tr>
<tr><td>Course Purpose</td><td colspan="5">The aim of the course is to familiarize students with fundamental concepts of linear dynamical systems analysis using state space techniques. The developed competences in the form of analytical tools are aimed for both performance evaluation, in terms of system stability controllability and observability, and controller design using state feedback, state observers and optimal control techniques.</td></tr>
<tr><td>Learning Outcomes</td><td colspan="5">By the end of the course, students must be able to:
1. Identify basic elements of matrix algebra, basis, orthonormalization, eigenvalues and eigenvectors, positive definiteness, Jordan Canonical Form, and Cayley Hamilton Theorem.
2. Identify state variables and derive linear and non-linear state-space equations of dynamical systems.
3. Linearize non-linear systems to derive linear approximations in standard state space form.
4. Derive Multiple Input Multiple Output transfer matrices from state space equations and derive state space realizations.
5. Compute the state transition matrix and solve the standard Linear Time-Invariant (LTI) State Space Equation.
6. Define Controllability and Observability and check for Controllability and Observability of LTI Systems using appropriate tests.
7. Analyse the stability of Dynamical Systems using the eigenvalues of the state matrix and Lyapunov stability theorems.
8. Apply pole placement via state feedback techniques.
9. Recognize the role of observers and design linear state observes.
10. Analyse feedback controller design in dynamic control systems using state Observer Design, Optimal control and Linear Quadratic Regulator (LQR) concepts.
11. Develop competences in developing or sketching the proofs for the controllability, observability and stability theorems.</td></tr>
</table>

Prerequisites	None	Corequisites	None

Course Content	**Introduction:** Review of matrix algebra, basis, orthonormalization, eigenvalues and eigenvectors, Laplace Transforms, Jordan Canonical Forms, Positive Definite Matrices and their properties, Cayley-Hamilton Theorem, Similarity Transformations. **State Space Representation:** State variables, State-space equations. Linearization of non-linear systems, Multiple Input Multiple Output Transfer functions, State space Realisation of Transfer Functions, Controllable/ Observable Canonical Forms. **Stability:** Input Output Stability, Internal Stability, Lyapunov Stability, Poles, Zeros, Jordan Canonical Form, Stability Theorem, Lyapunov Equation, Lyapunov Direct Method. **Linear time-invariant systems**: State Transition Matrix, Solution of linear time-invariant state equations, Controllability and Observability Definitions, Controllability/Observability Matrices., Controllability/ Observability Grammians, Theorem of Duality. **Feedback Controller Design and Optimal Control:** Pole placement with state feedback for Multiple Input Multiple Output Systmes, Optimal Control Design. Linear Quadratic Regulator (LQR) design, Riccati Equation. **Estimation:** Linear State Observers of Multiple Input Multiple Output Systems, Certainty Equivalence Principle.
Teaching Methodology	Students are taught the course through lectures (3 hours per week) in classrooms or lectures theatres, by means of traditional tools or using computer demonstration. Auditory exercises, where examples regarding matter represented at the lectures, are solved and further, questions related to particular open-ended topic issues are compiled by the students and answered, during the lecture or assigned as homework. Topic notes are compiled by students, during the lecture which serve to cover the main issues under consideration and can also be downloaded from the e-learning platform or the lecturer's webpage. Students are also advised to use the subject's textbook or reference books for further reading and practice in solving related exercises. Tutorial problems are also submitted as homework and these are solved during lectures or privately during lecturer's office hours. Furthermore, design projects may be assigned to the students, where literature search is encouraged to identify a specific problem related to some issue, gather relevant scientific information about how others have addressed the problem, implement to implement the design and report the results in written or orally. Where appropriate, taught material as well as examples and design problems are drawn from the recent research activities of the lecturer or other faculty members.
Bibliography	**(a) <u>Textbooks:</u>** • Chi-Tsong Chen Linear System Theory and Design, Third Edition, Oxford University Press, 1999.

	• J. Dwight Aplevich, **The Essentials of Linear State-Space Systems**, Wiley Text Books. **(b) References:** • G.F. Franklin, J.P. Powell and Enami-Naeini, ***Feedback Control of Dynamic Systems***, Pearson Prentice Hall 7th Edition, 2015. • R.C. Dorf and R.H. Bishop, ***Modern Control Systems***, Pearson Prentice Hall 12th Edition, 2011.
Assessment	The Students are assessed via continuous assessment throughout the duration of the Semester, which forms the Coursework grade and the final written exam. The coursework and the final exam grades are weighted 40% and 60%, respectively, and compose the final grade of the course. Various approaches are used for the continuous assessment of the students, such as mid-term written exam, oral exam, quizzes, design assignments and design projects. The assessment weight, date and time of each type of continuous assessment is being set at the beginning of the semester via the course outline. An indicative weighted continuous assessment of the course is shown below: • Assignments 10% • Homework 10% • Mid-Term written exams 40% • Design Project 20% • Quizzes 20% Students are prepared for final exam, by revision on the matter taught, problem solving and concept testing and are also trained to be able to deal with time constrains and revision timetable. The criteria considered for the assessment of each type of the continuous assessment and the final exam of the course are: (i) the comprehension of the fundamental concepts and theory of each topic, (ii) the application of the theory in solving related problems and (iii) the ability to apply the above knowledge in more complex design problems. The above criteria are weighted 30%, 40% and 30%, respectively. The final assessment of the students is formative and summative and is assured to comply with the subject’s expected learning outcomes and the quality of the course
Language	**English**