ELEC9731
Linear and Robust Control Systems

Course Outline – Term 1, 2021

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Professor Andrey Savkin Room 341 a.savkin@unsw.edu.au
Consultation Time: TBA

Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. ALL email inquiries should be made from your student email address with ELEC9731 in the subject line, otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Contact Hours

The course consists of 3 hours of lectures.

	Days	Time	Location
Lectures	Wednesday	18:00 - 21:00	On-line

Context and Aims

Aims of the course: Provide an introduction to linear system theory. Provide an introduction to robust and optimal control theory. Provide an introduction to optimal and robust filtering. The course covers the design of practical control systems.

Particular topics include:

1. Review of Matrix Methods and SISO State Space Methods.
2. Feedback Control of SISO Systems: Input/Output and State Space.
3. Tracking and Disturbance Rejection, Introduction to MIMO systems.
4. Polynomial Matrices and Smith-McMillan Form.
5. MIMO Decomposition and Balanced Realizations.
6. Introduction to Robust control, Kharitonov theorem, edge theorem.
7. Classical approach to robust control design, robust PID controllers, case studies.
8. Optimal control: dynamic programming; linear quadratic optimal control problem; Riccati equations.

9. Model predictive control, Kalman filtering.

10. H-infinity control, differential games; H-infinity filtering; case studies: robust control of biomedical systems, robust control of wind power systems.

Aspects of implementation are constantly emphasized.

Assessment

Assignment 1 25%	out - week 4 ; due - week 7
Assignment 2 25%	out - week 7 ; due - week 9
Final Exam (take home) 50 %	out - week 9 ; due - 20 days later

COVID-19

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health (https://www.nsw.gov.au/covid-19/what-you-can-and-cant-do-under-rules/self-isolation) or government authorities. Current alerts and a list of hotspots can be found here: https://www.nsw.gov.au/covid-19/latest-news-and-updates. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub (https://nucleus.unsw.edu.au/en/contact-us).

If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration (https://student.unsw.edu.au/special-consideration) through the Special Consideration portal (https://iaro.online.unsw.edu.au/special_consideration/home.login).

To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form (https://forms.office.com/Pages/ResponsePage.aspx?id=pM_2PxXn20i44Qhnufn7oy11mI4VSBBDg9xD1n2NSANUMUVYRlBRQ1BFTU1MMkZLQ0pHSjVMTk4yWi4u

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus (https://www.unsw.edu.au/sites/default/files/uploads/Safe%20Return%20to%20Campus%20Guide_students_v3.3.pdf) guide for students for more information on safe practices.

Course Details

Credits

This is a 6 UoC course and the expected workload is 10–12 hours per week throughout the 10 week term.

Relationship to Other Courses

This is a postgraduate course in the School of Electrical Engineering and Telecommunications.

Prerequisites and Assumed Knowledge

The main prerequisite for this course is ELEC3114. It is essential that you are familiar with a standard introductory undergraduate course on control engineering such as ELEC3114 before this course is attempted. The prerequisites also include some undergraduate courses on Linear Algebra and Probability.

Learning outcomes

After successful completion of this course, you should be able to:

1. describe basic aspects of linear system theory;

2. describe basic aspects of robust control theory;

3. describe basic aspects of optimal and robust filtering;

4. describe case studies from biomedical engineering and power systems;

5. solve basic problems in linear system theory;

6. solve basic problems in robust control;

7. solve basic problems in optimal and robust filtering.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in Appendix A. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in Appendix B). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in Appendix C.

Teaching Strategies

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding.
- Assignments to practice in problem solving, and to assess your progress.
- Take home examination to give the final test of competency.

Learning in this Course

You are expected to attend all lectures in order to maximise learning. You must prepare well for all lectures. In addition to the lecture notes, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is

also encouraged. UNSW assumes that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the term. Ongoing assessment occurs through the assignments and the final take home examination.

Relationship of Assessment Methods to Learning Outcomes

	Learning Outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Assignments	✓	✓	✓		✓	✓	
Final exam		✓	✓	✓	✓	✓	✓

Course Resources

Software:

- Matlab (including Simulink)

Textbooks

Prescribed textbooks:

- R.C. Dorf and R.H.Bishop. Modern Control Systems. Addison Wesley.
- G.C. Goodwin, S.F. Graebe and M.E. Salgado. Control Systems Design. Prentice Hall.
- J.B. Burl. Linear Optimal Control. Addison Wesley.

Reference books:

- T. Kailath. Linear Systems. Prentice Hall.
- I.R. Petersen and A.V. Savkin. Robust Kalman Filtering for Signals and Systems with Large Uncertainties. Burkhauser, Boston.
- I.R. Petersen, V.A. Ugrinovskii and A.V. Savkin. Robust Control Design Using H-innity Methods. Springer-Verlag.

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic

misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see: https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://my.unsw.edu.au/student/atoz/ABC.html), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and independent, self-directed study. In periods where you need to need to complete assignments, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult: https://student.unsw.edu.au/special-consideration.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods.

In particular, several practical case studies have been developed based on past students' feedback. During the last two years, two new case studies have been developed/significantly modified.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Appendices

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through home work.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Competency Standards	Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	1,2,3
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	1-3,5-7
	PE1.3 In-depth understanding of specialist bodies of knowledge	1,2,3
	PE1.4 Discernment of knowledge development and research directions	4
	PE1.5 Knowledge of engineering design practice	4,6,7
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	4
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	4
	PE2.2 Fluent application of engineering techniques, tools and resources	4,6,7
	PE2.3 Application of systematic engineering synthesis and design processes	5,6,7
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	4
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	4
	PE3.2 Effective oral and written communication (professional and lay domains)	5,6,7
	PE3.3 Creative, innovative and pro-active demeanour	4,6
	PE3.4 Professional use and management of information	1-4
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	