School of Electrical Engineering and Telecommunications

Term 2, 2021
Course Outline

ELEC3145
Real Time Instrumentation

COURSE STAFF

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Consultations: Lecturer consultation times will be advised via Moodle. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ELEC3145 in the subject line; otherwise they will not be answered.

Keeping Informed: All announcements will be made via 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 2-3 hours of lectures, a 1-hour tutorial, and a 3-hour laboratory session each week. Tutorials will start in Week 1 and laboratories in Week 2. Offline video recordings for both lectures and tutorials will be provided. The lectures and tutorials will be supported by online mentoring sessions. The labs will be run online by remote connection from your home computer to the computer setup in the laboratory room.

	Day	Time	Location
Lectures	Wed	9-12 (weeks 1-4)	Microsoft Teams Meeting
	Wed	10-12 (weeks 5-10)	Microsoft Teams Meeting
Tutorials	Thu	13-14	Microsoft Teams Meeting
Labs	Mon	12-15	Microsoft Teams Meeting

Context and Aims

This subject is offered in response to observations that real-time computing now plays a dominant part in the realization of most systems developed by electrical engineers in all sub- disciplines, and to insistence from industry that our graduates should be adequately equipped to deal with real-time systems. At the end of the course, students should be equipped with a set of skills and tools to be able to undertake a simple to moderately complex instrumentation project. To this end, the aim of the course is to:

- Provide an understanding of what real-time is, and its importance in many diverse areas of engineering.
- Teach students operating system concepts such as interrupts, multitasking, and data communication.
- Ensure the familiarity with the fundamentals of discrete-time systems, and their significance and representation on digital computers using C programming.
- Provide a basic understanding of physical instrumentation devices, such as A/D and D/A converters.
- Provide an understanding of fundamental systems theory concepts, including differential equations, transfer functions, state-space, numerical integration, and simple feedback (PID) control.

- Allow students to gain practical experience in dealing with the various parts of a simple real-time instrumentation and control system, using the real-time operating system RTAI.

Indicative Lecture Schedule

Period	Summary of Lecture Program
Week 1	Real Time and Discrete Time Systems, Control Systems Modelling
Week 2	State-Space Techniques
Week 3	Numerical Methods, PID Control
Week 4	Digital Controller Realisations
Week 5	Real Time Systems. **Mid-term exam**.
Week 6	Flexibility week
Week 7	Interrupts and Task Switching
Week 8	RTAI and Task Scheduling
Week 9	Inter-Process Communication
Week 10	A/D and D/A Conversion

Indicative Laboratory Schedule

Period	Summary of Laboratory Program
Week 1	-
Week 2	Lab 1 - MATLAB for Discrete-Time Systems
Week 3	Lab 2 – Numerical Methods in C and MATLAB
Week 4	Lab 3 – Linux and the GNU C compiler
Week 5	Lab 4 – RTAI and Real-Time Clock
Week 6	Flexibility week
Week 7	Lab 4 – continues
Week 8	Lab 4 – continues / Lab 5 – Real-Time Analog Data Acquisition in RTAI
Week 9	Lab 5 – continues
Week 10	Lab 5 – continues

Assessment

Laboratory Assessment	20%
Mid-term Exam	20%
Final Exam (2 hours)	60%

COVID19 - Important Health Related Notice

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 or government authorities. Current alerts and a list of hotspots can be found here. **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. 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 through the Special Consideration portal. 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.

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 guide for students for more information on safe practices.

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10-week term.

Relationship to Other Courses

This is a 3rd year course in the School of Electrical Engineering and Telecommunications. It is an elective course for students following a BE (Electrical) or (Telecommunications) program and other combined degree programs, and an elective for Computer Engineering students.

Pre-requisites and Assumed Knowledge

A satisfactory performance in either COMP1911: Computing 1A or COMP1917: Computing 1, or equivalent, is a required pre-requisite for basic programming skills.
Basic competency in First Year Mathematics is assumed. In addition, an introductory knowledge of C-programming will be required for the Laboratory Component.

Following Courses

A later course, ELEC4633, deals with systems which require increasing sophistication in software design and realisation, particularly in the design of executives, operating systems, and embedded systems.

Learning outcomes

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

1. Demonstrate an understanding of basic real-time operating system concepts, including interrupt processing, multitasking, inter-process communication.
2. Demonstrate an ability to undertake simple high-level real-time software design, specifically transforming a design specification into a description of software processes needed to support the design.
3. Demonstrate an understanding of, and an ability to effectively use, the RTAI operating system.
4. Use difference equations and discrete-time transfer functions as a means of describing discrete-time systems, and to be able to determine their stability.
5. Demonstrate the use of A/D and D/A converters, and understand their operation.
6. Use transfer functions, state-space, and block diagrams to describe and manipulate continuous time systems.
7. Describe how to use numerical methods such as Runge-Kutta integration and operator substitution for solving differential equations on a digital computer.
8. Demonstrate an understanding of what PID control is, how it is used effectively, and how it is implemented in a digital computer.

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 Standards as outlined in ***Appendix C***.

Syllabus

Real Time Instrumentation aims to equip students with the necessary and additional computing and hardware skills to be able to work with, and design real time computer systems which are connected as instrumentation and control devices to other electrical and mechanical circuits. The course is problem-based so that students will address the issues associated with, and concepts behind, building a simple real time computer system. The course revises the concepts of interrupts and introduces the concept of real-time computing, and discussing why time is important and how it is incorporated into a design, multitasking and multithreading and simple interprocess communication. Students will learn about, and be exposed to various devices providing an interface between a computer and the environment. Fundamental signal processing and control will be covered, including discrete-time processing, signal filtering and conditioning, state machines, PID control, and numerical integration. Although the course will exercise analytical skills, there is a strong emphasis on practical implementation using a Real Time Operating System, and using the C programming language to interface to, and control real hardware.

TEACHING STRATEGIES

Delivery Mode

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

- Formal lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Laboratory sessions, which support the formal lecture material and also provide you with practical construction, measurement and debugging skills;

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-term exam in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, 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 formal classes throughout the course.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class.

Laboratory program

The laboratory schedule is deliberately designed to provide practical exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend laboratory. Laboratory attendance will be kept, and you must attend at least 80% of labs.

Online labs will be run by remote connection from your home computer to the computer setups in the laboratory room. Further details on how to connect will be provided in Moodle. The labs will be supported online by lab demonstrators.

Emphasis within the lab program is on real-time concepts and instrumentation, NOT on learning how to use the Linux operating system and the C programming language. These concepts are in fact essentially treated as assumed knowledge. As such, the Linux OS, C and makefiles will not be taught in lectures and will be the responsibility of students to learn. The preliminary lab exercise addressing the Linux OS and C language is provided as an exercise to prepare students for the following laboratory exercises. It is recognized that some students will have less, or little experience in some or all of these areas, and so this exercise is particularly important. Further work will be required for these students initially so that they too feel confident in using these computer skills for the remainder of the laboratory program. It is expected that the preliminary exercise will be completed quickly.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator.

ASSESSMENT

The assessment scheme in this course reflects the intention to assess your learning progress through the term. Ongoing assessment occurs through the lab checkpoints (see lab manual) and the mid-term exam.

Laboratory Assessment

Assessment of the laboratory will consist of a mark given for checkpoint(s). Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. You are recommended to maintain a lab book for recording your observations.

It is essential that you complete the laboratory preparation before attending the lab.

After completing each experiment, your work will be assessed by the laboratory demonstrator.

Assessment marks will be awarded according to how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work (according to the guidelines given in lectures), and your understanding of the topic covered by the lab.

Mid-Term Exam

There will be an online mid-term exam in Week 5 (date, time to be advised). The mid-term examination tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any material already covered in the course schedule. It may contain questions requiring some (not extensive) knowledge of laboratory material, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

Final Exam

The exam in this course is a two-hour written examination, comprising several compulsory questions. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory). Marks will be assigned according to the correctness of the responses.

Note: For all assessment tasks, if you are unable to attend you can apply for special consideration. If the special consideration is granted, the assessment will be carried over to the final exam; i.e., the final exam percentage will be increased by the percentage of the assessment. For example, the final exam will be assessed for 80% instead of 60%, in case of missing the mid-term exam.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes							
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Laboratory	✓	✓	✓	✓	✓	✓	✓	✓
Mid-term test	-	✓	-	✓	-	✓	✓	✓
Final examination	✓	✓	✓	✓	✓	✓	✓	✓

COURSE RESOURCES

Textbooks

None of the texts gives an authoritative coverage of material in this course. However, there are several books that will be helpful for particular parts of the course. The first two will be useful for ELEC3145, and provide useful background material in real-time concepts, however will not be useful for those parts of the course dealing with digital filters and systems theory. Students may also consider purchasing a suitable C/C++ reference book.

Reference books:

- Alan C. Shaw, **Real-Time Systems and Software**, Wiley, 2001.
- Phillip A. Laplante, **Real-Time Systems Design and Analysis – An Engineer's Handbook**, IEEE Press, 1992.
- K. J. Astrom, B. Wittenmark, **Computer-Controlled Systems: Theory and Design**, 2nd edition, Prentice-Hall, 1990.
- Cay Horstmann, **Computing Concepts with C++ Essentials**, edition, Wiley, 2003.

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 on Moodle.

OTHER MATTERS

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

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://student.unsw.edu.au/policy), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **15 hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both formal classes and *independent, self-directed study*. In periods where you need to complete assignments or prepare for examinations, 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 can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application **prior to the start** of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. Be aware of the "fit to sit/submit" rule which means that if you sit an exam or submit an assignment, you are declaring yourself well enough to do so and cannot later apply for Special Consideration. For more information and how to apply, see 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 online student survey myExperience. 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. Based on the myExperience process feedback additional open labs will be arranged this year.

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:
https://student.unsw.edu.au/guide
https://www.engineering.unsw.edu.au/electrical-engineering/resources

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 and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.

Appendix C: Engineers Australia (EA) Professional Engineer Stage 1 Competency Standards

Competency Standards		Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	1-8
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	1-8
	PE1.3 In-depth understanding of specialist bodies of knowledge	1-8
	PE1.4 Discernment of knowledge development and research directions	
	PE1.5 Knowledge of engineering design practice	1-8
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	1-8
	PE2.2 Fluent application of engineering techniques, tools and resources	1-8
	PE2.3 Application of systematic engineering synthesis and design processes	1-8
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	1-8
	PE3.3 Creative, innovative and pro-active demeanour	1-8
	PE3.4 Professional use and management of information	1-8
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	1-8