UNSW SYDNEY Australia's Global University

School of Electrical Engineering and Telecommunications

Term 2, 2020
Course Outline

ELEC3145
Real Time Instrumentation

Course Staff

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Consultations: Online consultation/mentoring times will be advised in 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 UNSW student email address with ELEC3145 in the subject line, otherwise they may not be answered.

Keeping Informed:

All announcements will be made in 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

Indicative Contact Hours

The course consists of 2-3 hours of lectures each week, a 1-hour tutorial every week, and a 3-hour laboratory session every 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 and Time	Weeks
Lectures	Tue 9-10 Tue 9-12	Weeks 1-4 Weeks 5-10
Tutorials	Tue 12-13	Weeks 1-10
Labs	Thu 15-18	Weeks 2-10

Context and Aims

This subject is offered in response to observations that real-time computing now plays a dominant part in the realisation 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 purpose 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.

Schedule

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 test**.
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 Lecture Program
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 – Discrete-Time Filters in RTAI
Week 9	Lab 5 – continues
Week 10	Lab 5 – continues

Assessment

Final Examination	60%
Mid-term Test	20%
Laboratory	20%

Final Examination: The final examination will be online and last 2 hours plus additional time for uploading of answers.

Mid-term Test: There will be an online mid-term test in Week 5 (date, time to be advised). The aim of the test will be to assess one, or more, of the learning outcomes stated above.

Laboratory: Assessment of the laboratory will consist of a mark given for checkpoint(s).

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 test.

COURSE DETAILS

Credits

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

Assumed Knowledge

This is a 3rd year course in the School of Electrical Engineering and Telecommunications. The course is an elective in the Systems and Control discipline, focused on practical embedded digital control systems.

In ELEC2142, the emphasis is on dedicated real-time systems, which are connected as instrumentation and control devices to other electrical circuits. A later subject, ELEC4633, deals with systems which require increasing sophistication in software design and realisation, particularly in the design of executives, operating systems, and embedded systems.

A satisfactory performance in either COMP1911: Computing 1A or COMP1917: Computing 1, or equivalent, is a required pre-requisite for basic programming skills. Either ELEC2141: Digital Circuit Design, MTRN3200: Elements of Mechatronic Systems, or COMP3222: Digital Circuits and Systems are required pre-requisites for basic background in Digital Logic and Embedded Systems.

Basic competency in First Year Mathematics is assumed. In addition, an introductory knowledge of C-programming will be required for the Laboratory Component.

Course Objectives

The objective of this course is to equip students with the necessary skills to analyse, design and implement computer-based real time systems, as well as critically evaluate their performance. With this course and some further experience, students should be able to convert a worded problem specification into a functional and reliable real time solution which satisfies all requirements. Although real time systems encompass a very broad range of application areas, a central theme in this course is the application of real time computing for the purpose of signal processing and control.

The course aims to give students fundamental knowledge in real time operating systems, including scheduling, kernels, and inter-process communication, as well as skills in the effective use of embedded computers.

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.

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 both the C programming language and embedded Matlab toolboxes to interface to, and control, real hardware.

Graduate Attributes

Graduate attributes are those which the University and/or Faculty of Engineering agrees students should develop during their degree. Further information can be obtained in the document. This course aims to contribute to students attaining the following graduate attributes:

- The ability to engage in independent and reflective learning, addressed through the laboratory program exercises, and through independent assignment exercises.
- The skills of effective communication, which are addressed by tutorial and assignment problems and assessed in the final exam.
- The capacity for enterprise, initiative and creativity, which is addressed by the laboratory program, where students can use their initiative in solving the specified problems in a number of different ways.
- The capacity for analytical and critical thinking and for creative problem-solving, which is addressed by tutorial and lab exercises, again, where students need to provide critical evaluation of their solutions to problems in order to determine their merits and pitfalls.

Teaching Strategies

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

- Offline video lectures and online mentoring sessions, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Offline video tutorials and online mentoring sessions, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Online laboratory sessions, which are the central learning environment for this course, and will also provide you with practical construction, measurement and debugging skills.

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

Recommended Textbooks and Reading Material

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.

The Laboratory Program

The 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 demostrators.

Most of the work in this course is undertaken as problem-based learning within online laboratory program. Emphasis within the lab program is on digital filters, 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.

The labs will be available at the start of session, and students are encouraged to move through the laboratory exercises at their own pace.

Laboratory Exemption: There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses.

Online Resources

All material available in electronic format, will be available in Moodle:

https://moodle.telt.unsw.edu.au/login/index.php

Each student enrolled will be granted access to the ELEC3145 subject page in Moodle, where your login is your standard zPass login.

Moodle will be used for such things as:

- displaying/posting notices/messages;
- posting lecture notes / tutorial handouts / lab exercises / short quizzes;
- quizzes;
- hosting discussions (only related to the subject) between class/teacher class/class etc;
- posting grades as they become available.

It is encouraged that students seeking advice/help on matters related to the course material seek help from other students, either in person, or via the discussion board in 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/guide), 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 need to 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 online 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 Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	
	PE1.5 Knowledge of engineering design practice	✓
	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	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	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)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓

	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	✓