ENGG*4420*F17 Real Time Systems Design

(Rev. 4: Oct 13, 2017)

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1 Instructional support

1.1 Faculty

Instructor	Antony Savich
Office	THRN 2361
Contact	asavich@uoguelph.ca and Courselink
Office hours	after lectures or any time by appointment

1.2 Assistants

GTA	Graham Thoms
Contact	gthoms@uoguelph.ca and Courselink
Office & hours	by appointment

1.3 Lab Technicians

Primary technician	Kevin Dong
Office	RICH 2506
Contact	kdong@uoguelph.ca, x56455

For special equipment supplies, related to the project, Hong Ma (RICH 1504A, hongma@uoguelph.ca) can be contacted after discussing requirements with Antony or Graham.

2 Course resources

2.1 Website

Course material, news, announcements, and grades will be regularly posted to the ENGG*4420 Courselink site. You are responsible for checking Courselink regularly. It is envisaged that coursework deliverables, excluding exams, will be submitted by the students electronically via Courselink.

2.2 Required reading

1. Radu Muresan, Engg*4420 Real-Time Systems Design Lecture Notes, University of Guelph, Courselink System, 2016 (2017 as amended)
2. Radu Muresan, Engg*4420 Real-Time Systems Design Lab Manual, University of Guelph, Courselink System, 2016 (2017 as amended)

2.3 Recommended reading

1. Rajib Mall Real-Time Systems Theory and Practice, Pearson Education, 2008.
2. Giorgio C. Buttazzo, Hard Real-Time Computing systems, 3rd Edition, Springer, 2011.

3. Jane W. S. Liu Real-Time Systems, Prentice Hall, 2000.
4. C. M. Krishna, Kang G. Shin, Real-Time Systems, McGraw-Hill, 1997.
5. Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, Feedback Control of Dynamic Systems, 5th Edition, Prentice Hall, 2006.
6. Jean J. Labrosse MicroC/OS-III The Real-Time Kernel, Micrium, 2009.
7. Keil Tools, RTX Kernel, 2014.
8. Nimal Nissanke, Real-Time Systems, Prentice Hall, 1997.
9. Stuart Bennett, Real-Time Computer Control, Prentice Hall, 1994.

2.4 Additional resources

Lecture Information All the lecture notes are posted on the ENGG*4420 CourseLink system (week 1 to week 12) under *Lectures* module.

Lab Information The ENGG*4420 Real-Time Systems Design Lab Manual can be purchased from the University of Guelph bookstore and it is also posted on the ENGG*4420 CourseLink system under the *Labs* module.

Exams Some solutions of previous midterm exams will be posted on the ENGG*4420 CourseLink system under the *Exam Samples* section. Also, after midterm exam the solutions for the exam with the marking scheme applied will be posted for your reference. Please note that this year's midterm and exam may differ somewhat or significantly from the format of previous years - you are advised not to rely on past year expectations or assumptions. Having said that, the particulars of both exams (format, coverage, etc.) in this course will be discussed in detail at the appropriate intervals in lectures and Courselink announcements.

Misc. Information Other information related to real-time systems will be posted on CourseLink throughout the semester.

2.5 Communication

Please use lectures and lab sessions as your main opportunity to ask questions about the course. Major announcements will be posted to the course website.It is your responsibility to follow Courselink regularly.As per university regulations, all students are required to check their ¡mail.uoguelph.ca¿ e-mail account regularly: e-mail is the official route of communication between the University and its students. You can sign up for Courselink notifications of announcements, material posting, forum activity, etc. via email or sms delivery - you are encouraged to do so.

3 Assessment

3.1 Grade composition

Labs 45%.

All students will complete common labs, plus one of options 1-3. Due dates and submission instructions will be announced at introduction of each lab module.

Common to all students	
Lab 1	8% (4% demo + 4% report)[1]
Lab 2	14% (6% demo + 8% report)[2]
Option 1 - *LabView System Modelling*	
Lab 3	8% (4% demo + 4% report)[3]
Lab 4a	15% (6% demo + 9% report)[4]
Option 2 - *Simplified project creativity*	
Lab 4b	6% (3% demo + 3% report)[5]
Project	17% (7% demo + 3% presentation + 7% report)[6]
Option 3 - *Standard project creativity*	
Project	23% (10% demo + 3% presentation + 10% report)[7]

Midterm 15%

Date/time and room to be confirmed on Courselink in advance, and in coordination with students. It is expected no scheduling changes will need to be made and the midterm exam will be written in the lecture hall during a regularly scheduled lecture session.

Final Exam 40%

Wednesday Dec 6th, 14:30 16:30, Room TBA on WebAdvisor

3.2 Grading policy

Missed Assessments If you are unable to meet an in-course requirement due to medical, psychological, or compassionate reasons, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: `http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml`

Accommodation of Religious Obligations If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor at the start of the semester to make alternate arrangements. See the undergraduate calendar for information on regulations and procedures for Academic Accommodation of Religious Obligations: `http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml`

Passing grade In calculating a student's final grade for the course, the following conditions will be used:

1. Students must finalize and submit all the labs/project (Demo/Presentation + Report) and obtain a passing grade of 50% or higher in the lab component of the course. If an overall grade of lower than 50% is obtained in any lab or the project, the students need to arrange with the instructor and the teaching assistant to reschedule a new demo and report submission. No resubmission for this purpose

[1] F16 Lab Manual - Lab 1
[2] F16 Lab Manual - Lab 3
[3] F16 Lab Manual - Lab 2
[4] F16 Lab Manual - Lab 4
[5] Adapted LabView RTOS for Hot Air Plant
[6] Simplified FreeRTOS objectives
[7] Standard FreeRTOS objectives

will be accepted past last day of class. No submission with due accomodation/consideration can be accepted past grade submission deadline.

2. If any deliverable from the student's chosen lab option component remains outstanding (incomplete or failed with grade below 50%), or the final exam is missed, a final grade entry of "INC" will be forwarded to the Office of Registrarial Services at grade submission deadline for this course (see calendar).
3. Students must obtain a passing grade in the final exam or have an average:

$$(midterm\% + finalexam\%) \div 2 \geq 45\%$$

4. If the course passing conditions 1 and 3 are not met then the final course grade will be entered as 47% (lab component will not be considered in final grade calculation).

Contesting marks All laboratory and midterm test marks must be contested within 3 days from the grade submission. In addition, the exams must be written in permanent ink for contest considerations. Grades for any work written in pencil and the like shall not be eligible to be contested.

Missed midterm test If you miss the test due to grounds for granting academic consideration or religious accommodation, you will need to arrange a makeup test date with the instructor.

Lab work You must attend and complete all laboratories. If you miss a laboratory demo due to grounds for granting academic consideration or religious accommodation, arrangements must be made with the teaching assistant to complete a makeup lab demo.

Late lab reports Late submissions of lab reports will be accepted only with the approval of the course instructor. However, penalties on late submissions will apply. Applied penalties will be confirmed on Courselink per deliverable, and typically entail a 10-25% deduction per day late.

4 Course objectives and completion attributes

4.1 Course description (undergraduate calendar)

This course teaches real-time concepts from a system and computing perspective covering topics related to four major areas. Real-time computer control and system modeling area teaches basic real-time design and system modeling concepts for hard and soft real-time computer control applications. Real-time Operating Systems (RTOS) area introduces common kernel objects and inter-task communication and synchronization using examples from current commercial RTOS. Topics in the area of scheduling present theoretical results related to uniprocessor and multiprocessor scheduling algorithms and topics in the area of fault tolerance and reliability present current techniques at software and hardware level.

Prerequisites: ENGG*2400,ENGG*3640
Instructor suggested: ENGG*3410, CIS*3110, ENGG*3380

4.2 Goals

This course is a senior level course in most electrical and computer engineering programs and in most computer science programs. The main goals of the course are: a) to teach students the fundamental concepts in real-time systems, and b) to teach students how to develop real-time applications using modern real-time operating systems.

4.3 Learning objectives

At the successful completion of this course, the student will have demonstrated the ability to:

1. Efficiently model a system for the purpose of implementing real-time control.
2. Efficiently design and implement a real-time control algorithm.
3. Differentiate between different types of tasks (i.e., periodic, aperiodic, soft, hard, non-real-time) and properly use these tasks in the design.
4. Choose the appropriate RTOS (real-time operating system) for a specific application.
5. Design and implement real-time applications using commercial RTOS such as uC/OS, ARM RTX, FreeRTOS, MQX, and Real-Time LabView; be able to use appropriate kernel objects and services.
6. Understand and apply in the design of real-time systems the mechanisms of resource access protocols such as priority inversion protocol, the priority ceiling protocol and others.
7. Understand and apply in the design of real-time systems common uniprocessor and multiprocessor scheduling algorithms.
8. Understand the design safety and reliability components in real-time systems.
9. Apply the concept of simulation/experimentation for the purpose of designing and testing real-time systems.
10. Model using LabView a hot air plant system and optionally an automotive suspension system.
11. Design a real-time controller for a hot air plant and optionally for a semi-active automotive suspension system using uC/OSIII and Real-Time LabView.
12. Design real-time embedded applications for systems control.
13. Implement and demonstrate, through presentation, specified real-time control systems through lab work and course project.

4.4 Graduate attributes

Successfully completing this course will contribute to the following CEAB Graduate Attributes:

	Graduate Attribute	**Learning Objectives**	**Assessment**
1	Knowledge Base for Engineering	1, 2, 3, 4, 5, 6, 7, 8	Exams, Labs
2	Problem Analysis	3, 4, 5, 9, 10	Labs
3	Investigation	10, 11	Labs
4	Design	2, 5, 9, 10, 11, 12	Exams, Labs
5	Use of Engineering Tools	9, 10, 11, 12	Labs
6	Communication	13	Labs
7	Individual and Teamwork	9, 10, 11, 12, 13	Labs
8	Professionalism	-	-
9	Impact of Engineering on Society and the Environment	8	Exams
10	Ethics and Equity	-	-
11	Environment, Society, Business, & Project Management	-	-
12	Life-Long Learning	4, 5, 12	Labs

4.5 Instructor's role and responsibilities

The instructors role is to develop and deliver course material in ways that facilitate learning for a variety of students. All lecture notes plus various exercises, examples and referenced resources will be made available to students on Courselink system in the appropriate module. However, these are not intended to be stand-alone course notes. During lectures, the instructor will expand and explain the content of notes, cover adjunct subject matter and perspectives, and provide in class solutions to problems that supplement posted notes. Scheduled classes and labs will be the principal venue to provide information and feedback for tests and labs.

The instructor and TA will be happy to meet with students outside scheduled contact hours to facilitate a constructive and fruitful learning experience at the request of the students.

4.6 Strudents' role and responsibilities

Students are expected to take advantage of the learning opportunities provided during lectures and labs. In addition students are encouraged to consult the instructor and the TA in person outside scheduled contact hours or to contact the instructor or TA for any individual help needed. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

4.7 Relationship with other courses and labs

4.7.1 Previous Courses

ENGG*2400 (Engineering Systems Analysis) Analytical description and modeling of engineering systems such as electrical, thermal, automotive, and other control systems.

ENGG*3640(Microcomputer interfacing) Interfacing microcomputers to I/O external equipment, developing interfacing routines, understanding of the fabrics of the microcontroller architecture and programming. Understand synchronous and asynchronous serial communication and data acquisition topics.

4.7.2 Suggested Courses

ENGG*3410 (Systems and Control Theory) Subject matter includes control of dynamic systems (open and closed loop) with classical and modern algorithmic and analytical techniques. Extends system modelling skills and applications.

CIS*3110 (Operating Systems I) Operating system theory and practise, including the following components: scheduling, resource allocation, process management, multi-programming, multi-tasking, I/O control, file systems.

ENGG*3380 (Computer Organization and Design) Typically a complimenting course with ENGG*3640, covers CPU architecture and design, processor control, architecture classes, memory organization and performance.

4.7.3 Follow-on Courses

ENGG*4420 is a terminal course at undergraduate level. At graduate level:

ENGG*6550 (Intelligent Real-Time Systems) Soft real-time systems, hard real-time systems, embedded systems, time handling and synchronization, deadlines, preemption, interruption, RTS languages, RTS/ operating systems, system life-cycle, petri nets, task scheduling and allocation, fault-tolerance, resource management, RTS/search techniques, dealing with uncertainty.

5 Activities

5.1 Timetable

	Day	Time	Place
Lectures	Tue, Thu	13:00 – 14:20	MCKN 224
Lab (Sec 1)	Fridays	11:30 – 14:20	RICH 1504B
Lab (Sec 2)	Mondays	8:30 – 11:20	RICH 1504B

5.2 Lecture schedule (tentative)

Lecture	Lecture Topic	References	Learning Objectives
1-2	Definitions, Classifications and Characteristics of Real-time Systems and Real-Time Tasks	Lecture Notes	3
3	Design Example, Generalized Computer Approach, System Implementation Approach	Lecture Notes, Lab Manual	1, 2, 9, 11
4-5	Implementation of Real-Time Controller Designs Based on Plant Models	Lecture Notes	1, 2
6	Dynamic Models Approach for Real-Time Systems Control, Theory and Examples	Lecture Notes	1, 2, 9, 11, 12
6	Feedback Control, PID, Tuning, Application to Digital Real-Time Controllers	Lecture Notes	1, 2, 9, 11, 12
6	DDC Control Implementation of Real-Time Control Algorithms	Lecture Notes	1, 2, 9, 11, 12
7-10	Survey of Contemporary Real-Time Operating Systems, Benchmarks	Lecture Notes	4
11-12	Defining an RTOS, C/OSIII RTOS Architecture and Application Types	Lecture Notes	5
13-14	Critical Sections, Task Management, Special Tasks, Scheduling, Context Switch, Interrupt Management, Time Management	Lecture Notes	5, 7
15	Resource Management, Priority Inversion, Deadlocks, Synchronization	Lecture Notes	5, 6
15	Message Passing, Flow Control, Complex Example	Lecture Notes	5
16	MQX/FreeRTOS Basics: an RTOS for Uni-Processor, Multi-Processor and Distributed Processor Embedded Real-Time Systems	Lecture Notes	5, 7, 13
16	ARM RTX Basics	Lecture Notes	5,7
17-18	Uniprocessor Scheduling: Theory and Applications	Lecture Notes	7, 13
19	Real-Time Task Scheduling in Multiprocessor and Distributed Systems	Lecture Notes	7
20	Fault Tolerant Schedulability, Safety and Reliability in Real-Time Systems	Lecture Notes	8
21	Modeling Timing Constraints in Real-Time Systems	Lecture Notes	1

The lecture schedule and final topic selection, as well as lab schedule, are tentative and are subject to change. Course coverage will ensure Undergraduate Calendar Course Description, but will deviate based on student feedback and delivery improvements through the semester, in coordination with the students.

5.3 Design lab schedule

Week	Activity	References	Learning Objectives
2	Introduction to Lab 1 design requirements, equipment and design tools	Lab Manual	9, 12
3-4	Lab 1 implementation	Lab Manual	9, 10, 11, 12
5	Lab 1 demo		13
5	Introduction to Lab 2 design requirements and plant modeling	Lab Manual	9, 10, 11, 12
6-7	Lab 2 implementation	Lab Manual	9, 10, 11, 12
8	Lab 2 demo		13
8	Presentation for Laboratory Options 1-3, introduction to Lab 3 and Lab 4b	Lab Manual	5, 9, 11, 12

9	Lab 3/4b implementation, project proposals due	Lab Manual	5, 9, 11, 12, 13
10	Intro to Lab 4a, Lab 3/4b Demo, project implementation		13
11-12	Lab 4a/project implementation	Lab Manual	5, 9, 11, 12
$12\frac{1}{2}$	Lab 4a/project demos, project presentations		5, 9, 11, 12

5.4 Lab schedule

Week	Topic	Due
2	Introduction to Lab Equipment and Safety Training	
2-5	Lab 1: Modeling and control of a Hot Air Plant using LabView with serial communication to the real-time embedded platform	Week 6
6-8	Lab 2: Real-time embedded controller of a Hot Air Plant using an RTOS	Week 9
Option 1		
9	Lab 3: Real-time automotive suspension system simulation and control	Week 10
10-12	Lab 4: Multi-core real-time suspension controller using real-time LabView OS	Week $12\frac{1}{2}$
Option 2		
9	Lab 4b: LabView RTOS controller for Hot Air Plant	Week 10
10-12	Reduced scope project	Week $12\frac{1}{2}$
Option 3		
8-12	Project	Week $12\frac{1}{2}$

Week $12\frac{1}{2}$ means the last week of class, with Dec 1 being the last day of class. Dec 1 is a Monday schedule due to week 5 Thanksgiving and Fall Study Day carryover. Nov 30 is a Tuesday schedule due to same.

5.5 Other dates

First day of class	Thursday Sept. 7, 2017
Thanksgiving	Monday, October 9 - no classes, rescheduled to Friday December 1
Fall Study Day	Tuesday, October 10 - no classes, rescheduled to Thursday November 30
Last day to drop	Friday, November 3
Last day of class	Friday, December 1

You can refer the Undergraduate Calendar for the schedule of dates.

6 Lab safety

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible.

If the laboratory rules are not followed, consequences will include removing students access to the lab. If this results in lab work not being completed, the student will receive an "INC" grade report for the course.

7 Academic misconduct

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the Universitys policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of misconduct identification.

Please note, whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member.

7.1 Resources

The Academic Misconduct Policy is detailed in the Undergraduate Calendar: `http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml`

A tutorial on Academic Misconduct produced by the Learning Commons can be found at: `http://www.academicintegrity.uoguelph.ca/`

Please also review the section on Academic Misconduct in your Engineering Program Guide. The School of Engineering has adopted a Code of Ethics that can be found at: `http://www.uoguelph.ca/engineering/undergrad-counselling-ethics`

8 Accessibility

The University of Guelph is committed to creating a barrier-free environment. Providing services for students is a shared responsibility among students, faculty and administrators. This relationship is based on respect of individual rights, the dignity of the individual and the University community's shared commitment to an open and supportive learning environment. Students requiring service or accommodation, whether due to an identified, ongoing disability for a short-term disability should contact Student Accessibility Services as soon as possible, and follow up with the instructor as appropriate.

For more information, SAS can be reached at519-824-4120ext. 56208 or emailcsduoguelph.caor see the website:`https://wellness.uoguelph.ca/accessibility/`

9 Recording of materials

Presentations which are made in relation to course work, including lectures, cannot be recorded or copied without the permission of the presenter, whether the instructor, classmate or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

10 Other relevant resources

The Academic Calendars are the source of information about the University of Guelphs procedures, policies and regulations which apply to undergraduate, graduate and diploma programs: `http://www.uoguelph.ca/registrar/calendars/index.cfm?index`

11 General disclaimers

As is the spirit of all learning and teaching, the content of the course and its presentation in this outline are subject to continuous improvement. This course outline may be revised. Minor perfections may be made at the sole discretion of the instructor, with a post factum announcement to the students. If a revision is significant in nature, Undergraduate Calendar rules apply, and the changes necessitate, at the very least, a collaborative approach in consultation with the students and other stakeholders. In all cases, any changes proposed or made shall be done so in the spirit of elimination of any prejudice to the students.