The University of Western Ontario
Faculty of Engineering
Department of Electrical and Computer Engineering

ECE 4460B – Real-Time Embedded Systems

Course Outline for 2023 - 24

Descriptions:

The course covers various subjects pertinent to real-time embedded systems. Given the broad definition of embedded system as computing systems that are embedded into a larger product, the topics include a methodical procedure for designing real-time embedded computing systems, with special focus on real-time operating systems, and real-time issues pertinent to embedded control systems. Some hardware components required in designing an embedded system, interfacing to external devices, and control systems are also studied in this course. Upon completion of the course, students will have basic understandings of how to design, build, and integrate hardware and software for an embedded control application. Hands-on experience will be gained by studying practical examples, performing laboratory experiments.

Academic Calendar Copy: Review of embedded processors, real-time kernel configurations, task control blocks, memory requirements; interrupt service routines, real-time clocks/timers, multi-tasking, schedulability analysis, inter-task communication, signals, message queues, cooperative and pre-emptive multi-tasking, priority scheduling, priority inversion problems, timing considerations, deadline handing, input-output handling; practical issues in computer control; design, development, and testing techniques.

Contact Hours: 3 lecture hours, 4 laboratories, 3 hours each, 0.5 course.

Antirequisite: Former ECE 360A/B

Prerequisite: CS1027A/B or CS 1037A/B, CS 2211A/B or SE 2250A/B, ECE 3375A/B as well as successful completion of the third year of the Engineering program.

Unless you have either the requisites for this course or written special permission from your Dean to enrol in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

CEAB Academic Units: Engineering Science 60% Engineering Design 40%

Textbook (Required): The Course Booklet available at Book Store (Digital Copy)

Reference Materials:

1. Embedded Microcontrollers, Morton, Pearson Education, 2001 (ISBN 8131713334, 9788131713334)

2. Real-Time Concepts for Embedded Systems, Q. Li, CMPBooks, 2003 (ISBN-13 978-1-57820-124-2).
3. Embedded Systems: A Contemporary Design Tool, J.K. Peckol, John Wiley and Sons, Inc. 2008 (ISBN 978-0-471-72180-2).
4. Embedded System Design: A Unified Hardware/Software Introduction, F. Vahid and T. Givargis, John Wiley and Sons, Inc. 2002 (ISBN 0-471-38678-2)
5. Computers as Components: Principles of Embedded Computing System Design, Wayne Wolf, Morgan Kaufmann Publishers, 2001 (ISBN 1-55860-541-X). Details of the subsections are provided during the class. Available at Taylor Library: QA76.9.S88W64 2001.

GENERAL LEARNING OBJECTIVES

Knowledge Base	A	Use of Engineering Tools	D	Impact on Society and the Environment	
Problem Analysis	D	Individual and Team Work		Ethics and Equity	
Investigation		Communication		Economics and Project Management	A
Design	A	Professionalism		Life-Long Learning	

Notation: I –The instructor will introduce the topic at the level required. It is not necessary for the student to have seen the material before. D – There may be a reminder or review, but the student is expected to have seen and been tested on the material before taking the course. A – It is expected that the student can apply the knowledge without prompting (e.g. no review)

Topics and Specific Learning Objectives

Topic 1. Introduction to Real-Time (RT) Systems
- a. Formalisms of real-time systems
- b. Fundamental of timing analysis and response time
- c. Synchronizing asynchronous events

Topic 2. Real-Time Operating Systems (RTOS)
- a. RTOS kernel and its objects
- b. Cooperative multi-tasking
- c. Preemptive multi-tasking
- d. Multiple tasks and scheduling policies
- e. Inter-process communication mechanism (semaphore, mailbox, and message queue)
- f. Task Scheduling
- g. Resource sharing and resolving contentions

Topic 3. Working outside of the processor
- a. Computer as components
- b. Interfacing to local devices
- c. Inputs and output devices
- d. Interfacing to remote devices
- e. Model of inter-process communication

Topic 4. Embedded Systems and Practical Notes

a. Real-Time embedded systems
b. General control systems

Note: The above topics and the order in which they are taught are subject to adjustments and changes.

SPECIFIC LEARNING OBJECTIVES:

1. At the end of topic 1, students should be able to:

- Define the main requirements of a RT program (RT system)	KB3,EPM1, EPM2
- Determine the response time of a program to an event	KB3
- Understand the challenges of synchronizing asynchronous events	KB3
- Determine the CPU load	KB3,PA1,PA2

2. At the end of topic 2, students should be able to:

- Understand the difference between cooperative and preemptive multitasking	KB3
- Understand the difference between the tasks used in cooperative and preemptive multitasking	ET1
- Develop timed-event loop to run multiple tasks cooperatively	D1
- Determine the response time of cooperative tasks	KB3, PA2,PA3,D1
- Understand how a preemptive multitasking works	KB3,PA2,D2
- Use uC/OS II as a preemptive Real-Time Operating System (RTOS)	ET1,ET2
- Understand how tasks interact with each other through the kernel using these inter-task communication mechanisms	KB3, ET1,ET2
- Learn about task scheduling and understand the difference between static and dynamic priority scheduling	KB3, ET1,ET2
- Understand how to share resources in RT program and what potential problems (contentions) can occur	KB3

3. At the end of topic 3, students should be able to:

- Explain the functionality and usage of input and output devices	KB3
- Understand and implement basic interfacing with local devices	ET1
- Develop skills in interfacing with remote devices (serial communications)	KB3,ET1
- Grasp the concepts of inter-process communication in RT systems	KB3

4. At the end of topic 4, students should be able to:

- Describe the characteristics and requirements of real-time embedded systems	KB3,EPM1
- Understand the principles of general control systems	ET3
- Implement practical solutions for RT embedded system	ET3

EVALUATION:

		Maximum Penalties (*)	
Course Component	Weight	English	Presentation
Assignments	0%	NA	NA
Laboratory	10%	0%	0%
Quiz (2 quizzes)	30%	5%	NA
Final Examination	60%	5%	5%

To obtain a passing grade students must attend and complete all laboratories. Failing to attend a lab without permission will result in a final course grade of 48% or less.

Assignments: Assignments are posted on course online portal. Although, Assignments will not be used as a means of student's assessment in the course, Assignments provide important information that complements the learning experience and enrich student's understanding of each topic. Students must use Assignments as a tool for evaluating their knowledge and understanding of each topic. Solutions to selected number of questions (not all questions) in each Assignment will be posted about one week after each Assignment is posted.

Laboratory: The laboratory consists of 4 laboratory exercises. Each exercise includes a pre-lab work that must be completed prior to attending the lab. Each students must complete pre-laboratory work individually and submit (upload) the work as one single PDF file to the student's dedicated drop box on OWL prior to each lab session.

Late submissions for pre-laboratory work are not accepted. It is the student's responsibility to ensure that the files are upload properly to the OWL and that the files are free of errors.

Students will work in a group (two or three) that must remain the same throughout the semester. All students in the group must attend all laboratory exercises. During each laboratory exercise, each group must complete each part of the exercise and show the results to the TA before advancing to the next part. If the TA is busy and the group is waiting more than 5 minutes, they can advance to the next section and show the results for multiple parts together. The group must be able to regenerate the data for each part. It is the group's responsibility to make sure that the TA has seen the results for all parts of the laboratory exercise. The TA will ask the group questions related to the completed part at the end of the laboratory session and assign a mark to the group.

The mark for each lab exercise is based on,

(1) pre-laboratory work,
(2) attending in each lab session and demonstrating the results for the laboratory exercise, and
(3) answering questions following the completion of each part.

The amount of time required to successfully complete each lab is inversely proportional to the amount time dedicate to the preparation for the pre-lab. It is expected from students to dedicate sufficient time and effort to prepare for each lab session prior to attending the laboratory. The TA will not be able to extend the time required for the lab session. Students who cannot complete their lab exercise within the allocated time will receive partial mark for the pre-lab work, if submitted in advance, and the portion of the exercise completed.

If a student in a group is either absent or more than one hour late for a lab session, the remaining members of the group are still required to complete the lab exercise within the allocated time. In such cases, the absent student will receive a 30% deduction in their corresponding lab mark, unless they provide the necessary documentation to the Undergraduate Office. All documents for receiving accommodation must be submitted to the Undergraduate Office. Students should not inquire about missed labs from the instructor and/or TAs. Additionally, they should not seek confirmation regarding granted accommodations from the instructor.

Quiz: There are two quizzes throughout the semester. These quizzes will be held during the lecture hours. The date for the quizzes will be announced at least 1 week in advance of each quiz on the course website. The quizzes are closed-book and can include a mixture of questions require calculations, essay and explanation, and multiple choice questions.

If a student misses any of the quizzes, the quiz will not be rescheduled. The student who has missed a quiz must follow guidelines in Academic Consideration for Student Absence to provide necessary documentation to the Undergraduate Office. The Undergraduate Office will decide whether to allow the reweighting of the quiz, where reweighting means the marks allotted for the quiz will be added to the final exam. Students should not email the instructor to receive confirmation regarding their granted accommodations. Without accommodation, a student will receive a mark of zero for a missed quiz. Email inquiries regrading reweighting of missed quizzes will not be replied by the instructor.

If a student is going to miss a quiz for religious reasons, they must inform the undergraduate office in advance otherwise they will be required to write the quiz.

Final Examination: The final exam will be closed-book and will cover all topics taught during the lectures and laboratory sessions. Necessary equations will be provided. Only non-programmable calculators are permitted. (check https://studentservices.uwo.ca/secure/Exams/).

Late Submission Policy: Late submissions for assignments (if submission is required), pre-laboratory work or any other course deliverables are not accepted. It is the student's responsibility to submit (upload) the required files properly on the OWL and ensure that the uploaded files are free of errors.

Use of English Policy: In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

All work will be marked first for content after which a penalty not to exceed the maximum shown above may be applied for lack of proficiency in English and/or presentation.

Attendance: Any student who, in the opinion of the instructor, has not engaged sufficiently in on-line lectures and/or is absent too frequently from laboratory will be reported to the Dean (after due warning has been given). On the recommendation of the department, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

Academic Consideration for Student Absence: Students will have up to two (2) opportunities during the regular academic year to use an on-line portal to self-report an absence during the term, provided the following conditions are met: the absence is no more than 48 hours in duration, and the assessment for which consideration is being sought is worth 30% or less of the student's final grade. Students are expected to send an email to the instructor within 24 hours of the end of the period of the self-reported absence. You do not need to receive the instructor's acknowledgment for the self-reporting absence. Students are not able to use the self-reporting option in the following circumstances:

- for exams scheduled by the Office of the Registrar (e.g., December and April exams)
- absence of a duration greater than 48 hours,
- assessments worth more than 30% of the student's final grade,
- if a student has already used the self-reporting portal twice during the academic year

If the conditions for a Self-Reported Absence are not met, students will need to provide a Student Medical Certificate if the absence is medical, or provide appropriate documentation if there are compassionate grounds for the absence in question. Students are encouraged to contact their Faculty academic counselling office to obtain more information about the relevant documentation.
Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. All

documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.

When a student receives departmental approval for reweighting of a missed quiz, **the reweighting means the marks normally allotted for the quiz will be added to the final exam**. Email inquiries regrading reweighting of missed quizzes will not be replied by the instructor.

For Western University policy on Consideration for Student Absence, see
Policy on Academic Consideration for Student Absences - Undergraduate Students in First Entry Programs
and for the Student Medical Certificate (SMC), see:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf.

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the Western Multicultural Calendar.

For more information concerning Students Unable to Write Tests , see Western Engineering Guidelines at:
https://www.eng.uwo.ca/files/undergraduate/Instructions-for-students-unable-to-write-tests-or-exams-.pdf

Cheating and Plagiarism: Students must write their essays and assignments in their own words. Whenever students take an idea or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. University policy states that cheating, including plagiarism, is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning.

All required papers may be subject to submission for textual similarity review to commercial plagiarism detection software under license to the University for detection of plagiarism. All papers submitted will be included as source documents on the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between the University of Western Ontario and Turnitin.com (http://www.turnitin.com).

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, in the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Important Considerations:

To ensure the best experience for both you and your classmates, please honour the following rules of etiquette:

- please **"ARRIVE"** to class on time
- please do not use your cell phone during the class
- Keep in mind the different cultural and linguistic backgrounds of the students in the course.
- Be courteous toward the instructor, your colleagues, and authors whose work you are discussing.
- Be respectful of the diversity of viewpoints that you will encounter in the class and in your readings. The exchange of diverse ideas and opinions is part of the scholarly environment. "Flaming" is never appropriate.
- Be professional and scholarly in activities related to this course.

Note that disruptive behaviour of any type during classes is unacceptable. Students found guilty of disturbing a class may be subject to disciplinary measures under the Code of Student Conduct.

Policy on Repeating All Components of a Course: Students who are required to repeat an Engineering course must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment, or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted by the student for grading in subsequent years.

Internet and Electronic Mail Policy: Students are responsible for regularly checking their Western e-mail and notices posted on the course web site and making themselves aware of any information that is posted about the course.

Accessibility: Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 519-661-2111 ext. 82147 for any specific question regarding an accommodation.

Support Services: Office of the Registrar, http://www.registrar.uwo.ca/
Student Development Centre, http://www.sdc.uwo.ca/
Engineering Undergraduate Services, http://www.eng.uwo.ca/undergraduate/
USC Student Support Services, http://westernusc.ca/services/

Students that are in emotional/mental distress should refer to Mental Health @ Western, http://www.uwo.ca/uwocom/mentalhealth/, for a complete list of options about how to obtain help.