

# WATERLOO | ENGINEERING

## ECE 224: Embedded Microprocessor Systems

### Course Syllabus

Fall 2020

### *Course Description*

This course examines the design and implementation of embedded microprocessor systems from both hardware and software design perspectives. Bus architectures and bus interfaces are examined in detail. Synchronization and timing considerations are presented. Error detection and error correction are briefly introduced.

### *ECE 224: Embedded Microprocessor Systems*

LAB, LEC, TUT 0.50

Course ID: 013172

Microprocessor system architecture, bus systems, memory systems, peripherals, parallel interfaces, serial interfaces, analog interfaces, data transfer, synchronization, error detection/correction, testing and debugging.

Prerequisites: (ECE 124, ECE 222; Level at least 2B Computer Engineering or 2B Electrical Engineering) or (ECE 124, ECE 222; Level at least 3A Software Engineering).

Antirequisites: MTE 325

### *Territorial Acknowledgement*

The University of Waterloo acknowledges that we live and work on the traditional territory of the Attawandaron (Neutral), Anishinaabeg, and Haudenosaunee peoples. The University of Waterloo is situated on the Haldimand Tract, the land promised to the Six Nations that includes ten kilometers on each side of the Grand River.

More information on the [Haldimand Treaty of 1784](#) can be found online. To learn more about the purpose of territorial acknowledgements, please refer to the [CAUT Guide to Acknowledging Traditional Territory \(PDF\)](#).

# Contents

Course Description .....	1
ECE 224: Embedded Microprocessor Systems .....	1
Territorial Acknowledgement .....	1
Course Schedule .....	4
Lecture Schedule .....	4
Scheduling Notes .....	4
Contact Information .....	5
Course Instructor .....	5
Lab Instructor .....	5
Teaching Assistants.....	5
Key Learning Outcomes.....	6
Attendance and Participation.....	6
In Case of Illness .....	6
Topic Sequence.....	7
Lecture Topics.....	7
Tutorial Topics .....	8
Course Resources .....	9
Recommended Textbook.....	9
Other References of Potential Interest.....	9
Course Deliverables .....	10
Lab Tools Tutorial .....	10
Grading .....	10
Design Project.....	10
Grading .....	10
Late Policy.....	10
Weekly Quizzes.....	11
Final Assessment .....	11

Missing the Final Assessment .....	11
Due Dates .....	11
Note for Students Repeating the Course.....	12
Overall Grade Calculation .....	12
University Expectations and Policies .....	13
Academic Integrity.....	13
Grievance.....	13
Discipline.....	13
Appeals .....	13
Note for Students with Disabilities .....	13
Counselling Services .....	14
Intellectual Property.....	14

## ***Course Schedule***

In this remote offering of this course, the lectures, tutorials, and labs will be delivered online using LEARN. Lectures will be delivered asynchronously using a combination of short videos and narrated PowerPoint slides that will serve as micro lectures on a topic relevant to the course material. Tutorials will be conducted synchronously online and taped for the benefit of students who cannot attend the scheduled sessions. Labs will be replaced by project activities that will involve watching videos, answering quiz questions, and completing a design project.

### ***Lecture Schedule***

There is no set lecture schedule for this term. Lecture videos will be added to LEARN as they become available. All lecture videos will be provided on LEARN by the end of the last day of classes on Monday, December 7<sup>th</sup>.

### ***Scheduling Notes***

The University of Waterloo Calendar of Events and Academic Deadlines, the schedule of classes, and the Department of Electrical and Computer Engineering provides the following scheduling notes:

1. Classes start on Tuesday, September 8<sup>th</sup>.
2. Reading Week starts on Sunday, October 11<sup>th</sup>.
3. Reading Week ends on Sunday, October 18<sup>th</sup>.
4. Classes end on Monday, December 7<sup>th</sup>.
5. Pre-examination study day on Tuesday, December 8<sup>th</sup>.
6. Final assessment period starts on Wednesday, December 9<sup>th</sup>.
7. Final assessment period ends on Wednesday, December 23<sup>rd</sup>.
8. Unofficial grades begin to appear in Quest on Thursday, December 24<sup>th</sup>.
9. Standings and official grades are available in Quest on Thursday, January 21<sup>st</sup>.

## Contact Information

Piazza is the most effective way to ask questions about the course. If you have a question about the course, other students will likely have the same question. By posting your question on Piazza, the question and its answer will be accessible to all students. If you do not yet have access to Piazza, you may sign up using the following link:

<http://piazza.com/uwaterloo.ca/fall2020/ece224>

The access code for the course is 1209. Please do not share this access code with anyone.

If you need to contact the course instructor directly for more personal matters, please send an email to your course instructor's address with a subject line of "ECE 224 Course Question".

## Course Instructor

Students may book an online appointment to speak with the course instructor to inquire about any aspect of the course. All questions regarding course topics, course materials, deadlines, and grading should be directed to the course instructor. Regularly scheduled office hours for meeting with students will be announced on Piazza. An appointment is not needed during regularly scheduled office hours.

Instructor	Office Location	Campus Phone	E-mail Address
William (Bill) Bishop	My Basement	(519) 888-4712	<a href="mailto:wdbishop@uwaterloo.ca">wdbishop@uwaterloo.ca</a>

My campus phone has been setup to send all voicemail messages as voice recordings to my e-mail. If you phone me at the number listed above, I will receive your voicemail message immediately via e-mail.

## Lab Instructor

Students may book an online appointment to speak with the lab instructor to inquire about the lab studies, to discuss concerns about the conduct of teaching assistants, or to discuss concerns about the conduct of fellow students. Appointments may be booked by contacting the lab instructor via e-mail.

Lab Instructor	Office Location	E-mail Address
Kim Pope	A Secret Hideout in K/W	<a href="mailto:c3pope@uwaterloo.ca">c3pope@uwaterloo.ca</a>

## Teaching Assistants

Students may book an online appointment with the teaching assistant to discuss questions on course content. Appointments may be booked by contacting the teaching assistant via e-mail.

Teaching Assistant	Office Location	E-mail Address
Lucas Napoleão Coelho	Whereabouts Unknown	<a href="mailto:lcoelho@uwaterloo.ca">lcoelho@uwaterloo.ca</a>
Bo Yang	Whereabouts Unknown	<a href="mailto:b36yang@uwaterloo.ca">b36yang@uwaterloo.ca</a>

## ***Key Learning Outcomes***

The table below lists the key learning outcomes for the course. On successful completion of this course, a student should be able to do the following:

	<b>Key Learning Outcome</b>
1	Identify system realities (such as noise, jitter, metastability, and transmission line effects) and select suitable approaches for managing these realities in an embedded computer system.
2	Compare and critically assess design tradeoffs in an embedded computer system.
3	Analyze the effects of synchronization mechanisms on the operational characteristics of an embedded computer system.
4	Design hardware and software components to reliably connect devices to an embedded computer system.

## ***Attendance and Participation***

Students are expected to complete all online activities. If you are unable to attend a scheduled online tutorial, a recording of the tutorial will be made available on LEARN for you.

If you anticipate missing a deliverable deadline or an exam for a non-medical reason, you should contact your course instructor as soon as you are aware of the issue. Given sufficient notice, alternate arrangements may be possible. Alternate arrangements are rare and subject to the discretion of the course instructor.

## ***In Case of Illness***

The university has not provided guidance on how illnesses should be reported during the Fall term. If the procedures for reporting illnesses change, notification will be provided on Piazza. Quest provides a mechanism for self-reporting illness due to Covid-19. It is my understanding that a verification of illness form will not be required for incidents of Covid-19 but if you exhibit the symptoms of Covid-19, you should self-report the illness on Quest. In the absence of further clarification from the Faculty of Engineering, it is recommended that students who require academic accommodation for any illness e-mail the instructor immediately for guidance. Students will not be required to provide any details of the illness.

## Topic Sequence

Lecture and tutorial topics have been scheduled to maximize learning and to ensure adequate preparation for course deliverables. The course instructor may deviate from the schedule to spend more time where needed by students.

### Lecture Topics

The table below provides an estimate of the lecture hours for each topic as well as an overview of the content of each topic. You will find more detailed descriptions of each topic at the start of each section of the lecture notes.

Lecture Topic	Estimated Hours	Description
Course Introduction	1	An introduction to the teaching team, course expectations, deliverables, marking scheme, and a very brief introduction to interfacing concepts.
Embedded Systems	1	A review of the fundamentals of embedded systems and the terminology associated with embedded systems.
Interfacing Software, Introduction to Synchronization, and Device Drivers	1	A review of embedded software design concepts and synchronization concepts.
Synchronization, Data Generation and Data Transfer	2	A model for analyzing synchronization behaviour and performance and examples of synchronization analysis.
Computer Structure	4	A review of processor structure, instruction execution, clock signals, control signals, and bus interfacing.
Parallel Interfacing	3	A detailed examination of the design of parallel interfaces. This includes an examination of the role of the interface in matching bus timing and signaling characteristics with a device's timing and signaling characteristics.
Error Detection and Correction	2	An introduction to error detection and error correction including a discussion of error types, differences in detection and correction, and one example of an error correcting code (the Hamming code).
Serial Interfacing	6	An introduction to serial communication interfacing. This includes a comparison of asynchronous communication techniques and synchronous techniques as well as the protocols for serial communication.
Analog Interfacing	6	An introduction to digital-to-analog interfacing, analog-to-digital interfacing, and sample-and-hold circuitry. This includes a discussion of static and dynamic errors.
Buses - Data Transfer	3	A comparison of the functional behaviour and timing behaviour of synchronous, asynchronous, partially interlocked asynchronous, semi-synchronous, and split cycle bus systems. This section of the notes deals exclusively with the transfer of data.
Buses - Arbitration	3	A detailed examination of alternatives for bus arbitration including a discussion of the operation and characteristics of daisy chained and non-daisy chained bus arbitration techniques.
Direct Memory Access (DMA)	2	A brief examination of direct memory access including a discussion of hardware design implications, software implications, and system performance.
Grounding, Shielding, and Transmission Lines	2	An introduction to some of the real-world considerations that affect signal integrity when designing high-speed digital systems.

## ***Tutorial Topics***

In this course, the weekly tutorial sessions will typically be conducted by the course instructor or an experienced teaching assistant. The sessions are designed to offer additional insight into the course material. Each session will focus on a topic, assignment, or design project. Solutions to sample problems will be presented but no new course topics will be introduced. Students will have an opportunity to ask for help on course material. The table below provides a summary of the tutorial topics to be covered. This schedule is subject to change based on the perceived needs of the students.

<b>Tutorial Date</b>	<b>Tutorial Topic</b>
Friday, September 11 <sup>th</sup>	Welcome to the Course
Friday, September 18 <sup>th</sup>	Review of Fundamentals
Friday, September 25 <sup>th</sup>	Synchronization Techniques
Friday, October 2 <sup>nd</sup>	Generalized I/O Transfers
Friday, October 9 <sup>th</sup>	Computer Design Fundamentals
Friday, October 16 <sup>th</sup>	Reading Week
Friday, October 23 <sup>rd</sup>	Synchronous Buses and Parallel Interfacing
Friday, October 30 <sup>th</sup>	Error Detection and Error Correction
Friday, November 6 <sup>th</sup>	Serial Interfacing
Friday, November 13 <sup>th</sup>	Mini Design Project
Friday, November 20 <sup>th</sup>	Digital-to-Analog Conversion
Friday, November 27 <sup>th</sup>	Analog-to-Digital Conversion
Friday, December 4 <sup>th</sup>	Buses – Data Transfer

## Course Resources

The most significant course resources available on LEARN are listed below:

- The LEARN calendar provides reminders of important dates for the course. Students are encouraged to refer to this calendar regularly.
- The Introduction module provides links to the Faculty of Engineering Course Responsibilities website, the course syllabus, and presentations on promoting student wellness.
- The Lectures module provides links to the micro-lectures for the course. These videos will be added as the course progresses. Students may be required to complete viewing of one set of micro-lectures to gain access to the next set of micro-lectures in the series.
- The Labs module provides links to all materials required for completion of the online Lab Tools Tutorial.
- The Tutorials module provides links to the taped tutorial sessions and supporting materials.
- The Assignments module provides links to problem sets for the purpose of assessing your knowledge of the course material. Solutions to these problem sets will also be made available.
- The Examinations module provides links to previous exams and their solutions. You may use these exams to assess your preparation for the quizzes and exams in the course.
- The Virtual Classroom provides access to scheduled meetings via BONGO.
- Piazza will be used as the official discussion forum for questions on lectures, tutorials, labs, assignments, and exams. Piazza will be monitored by the teaching team.

## Recommended Textbook

There is no recommended textbook for this course.

## Other References of Potential Interest

W. Bishop, R. Gorbet, C. Hulls, and W. Loucks, *Lecture Notes – ECE 224: Embedded Microprocessor Systems*, Lecture Notes, University of Waterloo, Fall 2019.

C. Hamacher, Z. Vranesic, S. Zaky, and N. Manjikian, *Computer Organization and Embedded Systems*, Sixth Edition, McGraw-Hill Education, 2011.

Z. Vranesic and S. Zaky, *Microcomputer Structures*, Saunders College Publishing, 1989.

## ***Course Deliverables***

The course deliverables consist of a Lab Tools Tutorial, a Design Project, Weekly Quizzes, and a Final Assessment.

### ***Lab Tools Tutorial***

In this online offering of ECE 224, students will be asked to individually review the online Lab Tools Tutorial materials and complete a quiz on the use of the tools. The Lab Quiz will be made available on LEARN on Thursday, October 1<sup>st</sup> @ 9:00 am.

In the Lab Tools Tutorial, students will be introduced to the design of a system-on-a-programmable chip (SOPC) using the Intel Quartus Prime tools. Students will observe the acts of designing, building, and testing a 32 bit microprocessor system based on the Nios II processor core. Following the completion of the tutorial video, students will be required to complete a quiz where they will be asked questions on the proper use of the tools. Students will have one attempt to complete the quiz successfully.

### ***Grading***

The Lab Quiz provided on LEARN will be used to determine the Lab Tools Tutorial grade. Upon the submission of the quiz, students will receive a Lab Tools Tutorial grade out of 10 marks.

### ***Design Project***

Students participating in teams of four assigned by the course instructor will be asked to complete a Design Project (DP) that encourages students to conduct research into data converters and critically assess the usefulness of the devices for an embedded system application. The purpose of this project is to provide students with experience tackling an open-ended design problem in preparation for their 4<sup>th</sup> year design project. To complete the project, students must submit two reports. The Selection Report (SR) proposes four data converters to be considered for use in the embedded system design. Each team member is responsible for researching data converters online and proposing one of the four data converters in the report. The Recommendation Report (RR) recommends the best data converter for the application from the four described in the Selection Report. Additional details on the design project will be provided on LEARN once the topic of Analog Interfacing has been presented in the online lectures.

### ***Grading***

Grading rubrics will be provided on LEARN for both the Selection Report (SR) and the Recommendation Report (RR). Each report will be assigned a grade out of 10. In total, the mini design project is worth 20% of your final grade in this course.

### ***Late Policy***

If you submit either report more than 2 days late, late penalties will apply. The late penalty is 20% of the deliverable's maximum value per late day. Reported illnesses and other accommodations will be taken into consideration, if appropriate.

## Weekly Quizzes

Every week throughout the term, a quiz will be placed on LEARN to assess student progress through the course material. The quizzes will appear every Monday @ 9:00 am and end on Tuesday @ 5:00 pm. There will be 11 quizzes with the first one appearing on Monday, September 14<sup>th</sup> and the last one appearing on Monday, November 30<sup>th</sup>. Each quiz will be graded out of 5. The best 10 quiz grades will be used to compute the grade for the Weekly Quizzes in the course.

A missed quiz will be assigned a grade of 0 unless accommodation has been arranged. Note that no quiz will be held during Reading Week.

## Final Assessment

The final assessment will consist of a set of open-ended design questions. Submissions will be marked to produce a grade out of 20 for the final assessment. The final assessment will go online at 9:00 am on December 14<sup>th</sup> and remain online until Friday, December 18<sup>th</sup> @ 5:00 pm. It is expected that the final assessment will require 2.5 hours to complete.

Collaboration on the final assessment is not permitted. While students may refer to the online course materials and may ask for clarifications from the teaching team on the final assessment, students must not share answers electronically. All students are expected to behave with integrity.

## Missing the Final Assessment

Missing the final assessment due to a reported illness will result in an assigned grade of INC (Incomplete). The grade of INC (Incomplete) must be resolved by the completion of the final assessment within 4 months of the end of the course. If the final assessment is not completed within this timeframe, the grade will be automatically converted into a numeric grade representing the lesser of the grade earned and a grade of 46%. If the illness is not properly reported, a grade of DNW will be submitted for the student.

## Due Dates

Course Deliverable	Due Date
<b>Lab Tools Tutorial (LTT)</b> (Approximately 5 Hours)	Thursday, November 5 <sup>th</sup> @ 5:00 pm
<b>Design Project - Selection Report (SR)</b> (Approximately 10 Hours)	Thursday, November 26 <sup>th</sup> @ 5:00 pm
<b>Design Project - Recommendation Report (RR)</b> (Approximately 10 Hours)	Thursday, December 3 <sup>rd</sup> @ 5:00 pm
<b>Weekly Quizzes</b> (Approximately 1 Hour Each)	Tuesdays @ 5:00 pm
<b>Final Assessment</b> (Approximately 2.5 Hours)	Friday, December 18 <sup>th</sup> @ 5:00 pm

## Note for Students Repeating the Course

The online offering of this course uses substantially different assessment techniques from previous offerings of this course. For this reason, repeating students are expected to complete all course deliverables as if they were taking the course for the first time. The following material provides further clarification:

### Do I have to do the Lab Tools Tutorial and the Design Project again?

- *Yes, repeating students are expected to participate fully in the course.*

### Can I reuse material from previous submissions?

- *Yes, but you must ensure the following:*
  1. If you intend to reuse material from previous submissions, full disclosure is required. The previous submission must be clearly referenced (previous course, term, and partner(s) during that previous term as well as the mark received). You should also clearly indicate what has changed from your previous submissions.
  2. You will need to get permission from your previous partner(s) to share their intellectual property with your new partner.
  3. You will need to disclose to your new partner that you are reusing previously submitted work.
  4. Although you may use the previous work (with reference), you will be expected to update the work and correct deficiencies. Your new work should reflect your added understanding of the material.

If you have any other questions related to repeating the course, please e-mail your course instructor.

## Overall Grade Calculation

Your overall grade will be computed using the following deliverable weights:

Course Deliverable	Deliverable Weight
Lab Tools Tutorial	10%
Design Project	20%
Weekly Quizzes	50%
Final Assessment	20%

The instructor reserves the right to use alternative grading schemes in special circumstances. For example, if an accommodation is necessary, an alternative grading scheme may be used to the benefit of the individual student.

# University Expectations and Policies

The following statements represent university expectations and policies with respect to academic integrity, grievances, discipline, student appeals, and academic accommodations. If you would like more clarification, please contact your course instructor directly.

## Academic Integrity

*In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check the [Office of Academic Integrity](#) for more information.*

## Grievance

*A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read [Policy 70, Student Petitions and Grievances, Section 4](#). When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.*

## Discipline

*A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for his/her actions. Check the [Office of Academic Integrity](#) for more information. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to [Policy 71, Student Discipline](#). For typical penalties, check [Guidelines for the Assessment of Penalties](#).*

## Appeals

*A decision made or penalty imposed under [Policy 70, Student Petitions and Grievances](#) (other than a petition) or [Policy 71, Student Discipline](#) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to [Policy 72, Student Appeals](#).*

## Note for Students with Disabilities

*[AccessAbility Services](#), located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with [AccessAbility Services](#) at the beginning of each term.*

## **Counselling Services**

Counselling Services offers a variety of confidential services to University of Waterloo students. Counselling Services is located on the 2<sup>nd</sup> floor of Needles Hall North (the new addition to Needles Hall). The phone number for Counselling Services is (519) 888-4567 ext. 32655.

Counselling Services is currently providing services by phone and video on weekdays between 8:30 am and 4:30 pm. For those in need of counselling outside of these working hours, students are encouraged to take advantage of the following resources:

1. Good2Talk: A free confidential help line for post-secondary students 1 (866) 925-5454
2. Grand River Hospital: Offering 24/7 emergency care for mental health emergencies. 834 King Street West, Kitchener (519) 749-4300 ext. 6880
3. Here 24/7: Waterloo Region's Mental Health and Crisis Services team 1 (844) 437-3247
4. UW Police Services: Offering 24/7 assistance for all on-campus emergencies (519) 888-4567 ext. 22222

## **Intellectual Property**

*Students should be aware that this course contains the intellectual property of their instructor, TAs, and/or the University of Waterloo. Intellectual property includes items such as:*

- *Lecture content, spoken and written (and any audio/video recording thereof);*
- *Lecture handouts, presentations, and other materials prepared for the course (e.g., PowerPoint slides);*
- *Questions or solution sets from various types of assessments (e.g., assignments, quizzes, tests, final exams); and*
- *Work protected by copyright (e.g., any work authored by the instructor or TAs or used by the instructor or TAs with permission of the copyright owner).*

*Course materials and the intellectual property contained therein, are used to enhance a student's educational experience. However, sharing this intellectual property without the intellectual property owner's permission is a violation of intellectual property rights. For this reason, it is necessary to ask the instructor, TAs, and/or the University of Waterloo for permission before uploading and sharing the intellectual property of others online (e.g., to an online repository).*

*Permission from an instructor, TAs, or the University of Waterloo is also necessary before sharing the intellectual property of others from completed courses with students taking the same/similar courses in subsequent terms/years. Doing so without permission is considered a violation of intellectual property rights.*

*Please alert the instructor if you become aware of intellectual property belonging to others (past or present) circulating, either through the student body or online. The intellectual property rights owner deserves to know.*