ECE 298 – Instrumentation and Prototyping Laboratory
Course Outline – F2024

Course Description

"Practical aspects of analog and digital instrumentation. Prototyping such as printed circuit board design and manufacture."

Getting any electronic design from a concept to a PCB assembly requires knowledge with practical engineering techniques, with design development software and with Lab instrumentation. This course provides students with an opportunity to expand their levels of experience in these areas.

This course will begin with a FIXED (or CLOSED-ENDED) project design (one that is fixed in function and can't be changed) as the first project (it is non-embedded….no CPU/MCU). Each student taking the course will be working on this project individually. Each student will be purchasing a kit from the W Bookstore to build a PCB assembly of a non-embedded design. Later in the term, each student will demonstrate its functionality to the teaching team and the soldering quality and build quality and performance will be reviewed.

The purposes of this first project are the following:

1) TO DEVELOP SOLDERING SKILLS.
2) TO GAIN FAMILIARITY WITH SOME ELECTRONIC PARTS AND PACKAGING and basic Printed Circuit Boards.
3) TO GAIN FAMILIARITY WITH THE USE OF LAB EQUIPMENT.

This course will also focus on developing an OPEN-ENDED solution for a second project. Students will choose how to implement a solution from a number (albeit limited) of solutions. This second project will begin in the second Lab session. The solution must be an Embedded system on a prescribed MCU platform.

(STMicro NUCLEO64-F401RE). Students will work in teams of two to design a feasibility model of a solution and then prepare for it a prototype development cycle. Students will submit parts of their project design details during the course and provide technical documentation as though their project will be assigned to an incoming co-op student or colleague engineer.

The purposes of this second project are the following:

1) TO EXPLORE THE REQUIREMENTS FOR A TYPICAL PROJECT DEVELOPMENT.
2) TO EXAMINE PART DATASHEET CONTENT BEFORE DESIGNING A FEASIBILITY MODEL.
3) TO BUILD AND TEST THE FEASIBILITY MODEL WITH LAB INSTRUMENTS.
4) TO DEVELOP AND PRESENT A PROTOTYPE DESIGN FOR A MINI-DESIGN REVIEW.
5) TO PREPARE A PCB DESIGN AND DOCUMENTATION FOR A PROTOTYPE DESIGN SUBMISSION

Here is some relevant feedback from a student who took the course (on-campus version):

> *This is an informal email I wanted to write to praise ECE 298, which I took during the Spring 2019 term. One of the goals of the course was to help students get a bit more hands-on embedded experience, which can help for coop. Fast forward to March 2020, and during an interview I was having for an embedded software developer position, I showed off some of the code and demo videos for the wheelchair project I did for that course. The interviewing developer was so impressed, that is why I am currently working with them this summer (which is especially lucky, in these uncertain times).*
>
> *Kind regards, 2B student 2019*

The Intended Learning Outcomes for this course include (the numbers in brackets below are the relevant ECE Program-Level Indicator):

By the end of this course, students should be able to

- (5c) **Apply** the workflow for designing and assembling embedded systems
- (4a) **Define** requirements and specifications for an open-ended design problem
- (4bc) **Generate** and **refine** potential solutions to an open-ended design problem
- (6a) **Contribute** as an active team member to complete individual tasks
- (6b) **Collaborate** with others to complete tasks effectively as a team
- (7a) **Generate** documentation to communicate within the profession

Level: At least 2B Computer Engineering or Electrical Engineering
Prerequisites: None (but a basic knowledge of ":C" will be helpful)
Antirequisites: None
Details of this course syllabus are subject to change throughout the term

Course/Lab Instructor	**Kim Pope, BAsc (EE), P.Eng.** Email: kim.pope@uwaterloo.ca
Course Co-Creator:	**Prof. Derek Wight**

Notes and Textbook:

- Course website on **LEARN**
- Discussions on **Piazza**
- **Required IDE:** STM32Cube (provided on ECE Lab Computers)
- **Required EDA Tool:** Proteus (provided on ECE Lab Computers)
- **Optional:** P. Horowitz and W. Hill, *The Art of Electronics*, 3rd Ed., Prentice-Hall, 2015. ISBN-10: 0521809266. ISBN-13: 978-0521809269
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KITS:

It is expected that students purchase (and bring to the lab sessions) some kits from the W-Bookstore for this course.

i) ONE Timer V5 Project Kit (Non-Embedded project LAB A) **for each student**;
ii) ONE **Team-based** Nucleo-F401RE Board with USB Cable (LAB B); Alternatively, you may re-use one from your ECE-198 course in first year of engineering.
iii) ONE **Team-based** Project Kit for the Embedded project (LAB B);

Grading

All grade items, marking rubrics, and guidelines will be available on LEARN ahead of the deliverables.

Course Deliverable	Weight	
Lab A – N<u>on-Embedded Project:</u> <u>Digital Timer</u> The design is covered and some basics about the Proteus tools. Learn about signals and circuit connections and about basic soldering. Learn about what Lab Instruments can measure in a project development. The Meter & Oscilloscope will be covered. **LAB A DEMO's are Required (see Schedule due date)**	20%	**P C B A**
Lab B1 <u>–Embedded Project: Initial Feasibility Development</u> Embedded Project Details are covered and how to plan a design process. Explore the capabilities of the MCU on-chip peripherals and some of the Integrated Development Environment (IDE). Explore some signal interface patterns (PWM, SERIAL Comm. Analog to Digital, GPIO) and look at Part datasheets for the course Embedded Project. Signaling levels will be covered for 5V/3.3V TTL and CMOS. **Lab B1 Quiz is Required**	10%	**F E A S I B I L I T Y**
<u>Lab B2 –Embedded Project: Final Feasibility Model Development and DEMO</u> Develop the Project functions using a breadboard as a platform to interface kit components and the MCU Development board. Develop the MCU code to operate each component interface circuit **<u>individually first.</u>** Then **<u>integrate</u>** use your design using all components and interfaces with your completed Prototype MCU code for the final Feasibility Model solution. Measure and confirm signals in the breadboard design are within the device signal specifications. **Lab B2 Quiz is Required**	10%	
<u>Lab B3 –Embedded Project: Schematic Design and Final Feasibility Model DEMO & FEASIBILITY MODEL DESIGN REVIEW:</u> Develop a schematic of the Final Feasibility Model design using Proteus tools. Present your design with appropriate metrics. Create NET CLASSES in the schematic. Create a Video for a mini-Design Review of your Feasibility Model schematic Design. **Lab B3 Quiz is Required** **FINAL FEASIBILITY MODEL DEMO Development Begins** **FINAL FEASIBILITY MODEL VIDEO FOR DESIGN REVIEW Begins**	10% 20% 15%	
<u>Lab B4 –Embedded Project: Prototype Development and Report</u> Cover the PROTOTYPE MODEL schematic and a PCB assembly details using Proteus tools. Create a Bill of Materials and Gerber files using Proteus. Cover all design details and organize them for a Prototype Report. **PROTOTYPE MODEL Report Development Begins**	15%	**P R O T O T Y P E**

Lab B5 –Embedded Project: FINAL LAB SUPPORT . **FINAL FEASIBILITY MODEL DEMO EVALUATIONS** **PROTOTYPE MODEL REPORT SUBMISSIONS**		

Course Schedule

The following dates are also in LEARN. For any discrepancies or adjustments that may arise over the term for Lab deliverables, the LEARN content will take precedence.

F2024 ECE-298 LABS SCHEDULE					Comments
	M T W Th F 2 3 4 5 6 1	M T W Th F 9 10 11 12 13 2	M T W Th F 16 17 18 19 20 3	M T W Th F 23 24 25 26 27 4	
SEPT		COURSE OUTLINE LAB A PRESENTATION - NON-EMBEDDED PROJECT TIMER KIT IS REQUIRED		LAB B1 -PRESENTATION: EMBEDDED PROJECT AND INITIAL FEASIBILITY MODEL Lab A DEMO's DUE BY END OF LAB B1	TEAMS CHOSEN BY SEPT 13 ; LAB A STARTS SEPT 9; LAB B1 STARTS SEPT 23 LAB A DEMO's during LAB B1
	30 1 2 3 4 5	7 8 9 10 11 6	14 15 16 17 18 7	21 22 23 24 25 8	
SEPT / OCT		LAB B2 -PRESENTATION EMBEDDED PROJECT - FINAL FEASIBILITY MODEL LAB B1 QUIZ DURING LAB B2	READING WEEK	MIDTERM EXAM WEEK	LAB A DEMO's DURING WEEK 5 LAB B2 STARTS OCT 7 LAB B1 QUIZ DURING LAB B2
	28 29 30 31 1 9	4 5 6 7 8 10	11 12 13 14 15 11	18 19 20 21 22 12	
OCT/NOV	LAB B3 PRESENTATION: EMBEDDED PROJECT - FEASIBILITY MODEL SCHEMATIC AND PREP FOR TEAM FEASIBILITY MODEL DESIGN REVIEW VIDEO LAB B2 QUIZ DURING LAB B3		LAB B4 PRESENTATION: EMBEDDED PROJECT: PROTOTYPE SCHEMATIC AND PCB DESIGN FILE PREPARATIONS AND FINAL REPORT DETAILS. TEAM FEASIBILITY MODEL DESIGN REVIEW VIDEOS DUE BY END OF DAY FOR LAB B4.		LAB B3 STARTS OCT 28 LAB B2 QUIZ DURING LAB B3. LAB B4 STARTS NOV 11 LAB B3 QUIZ DURING LAB B4 PROTOTYPE DESIGN PRESENTATION VIDEOS DUE BY END DAY OF LAB B4
	25 26 27 28 29 13	2 3 4 5 6 14			
NOV/DEC	LAB B5: FINAL FEASIBILITY MODEL DEMO's	PROTOTYPE REPORTS DUE BY DEC 3			LAB B5 STARTS NOV 25 FINAL FEASIBILITY MODEL DEMO's DURING LAB B5 NO QUIZ DURING LAB B5 FINAL PROTOTYPE REPORT IS DUE BY END OF DAY ON DEC 3

Lab Overviews

The content for each lab will be presented at the beginning of each lab session. The instructor will go over the lab procedures and expectations and answer questions. Students MUST attend the Lab Sessions for the course. Absences will have marks penalties applied **unless the Lab Instructor IS NOTIFIED BY EMAIL BEFORE the Lab Session**. There will be Attendance Sheets.

Quizzes

Your experiences working through the lab materials and completing the lab deliverables are all the studying you need for the three lab quizzes. These quizzes are available **24 hours before and after the deadline**. The quiz answer will become available for review 24 hours after the deadline. STUDENTS MUST TAKE RESPONSIBILITY FOR COURSE QUIZ DUE DATES.

ONLINE Q&A Sessions

After the first Lab Session for the term is completed, the Lab Instructor can add ONLINE Q&A Session meeting(s) for each lab's content. The scheduling will be determined later, and notices will be provided on LEARN.

PROJECT DEMONSTRATIONS

There will be two demos to be done by each team. The first one is for the Non-Embedded Project and the other one is with the Embedded Project. See the schedule for the dates for these demonstrations.

The Non-Embedded Project will require a Printed Circuit Board Assembly to be built with some current integrated device technology and will involve hand-soldering. Lab Instruments will be employed to validate signal activities.

The Embedded Project demonstration, will cover the entire Embedded System operation with all devices working in unison with the MCU software and hardware interfaces.

Project Prototype Lab Report Submissions on Learn

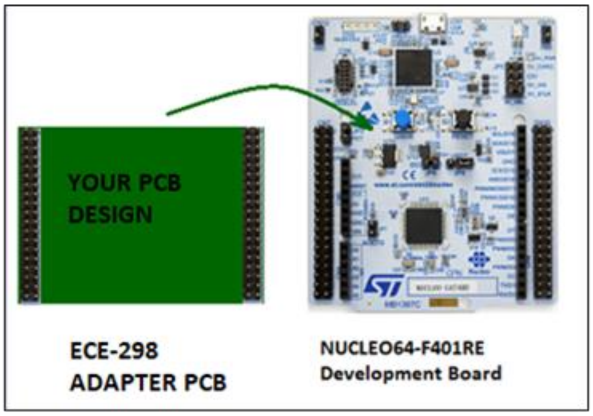
STUDENTS MUST TAKE RESPONSIBILITY FOR REPORT DUE DATES. Group submission drop boxes will be set up for the only Lab Report (Prototype Model Report) with the due date applied. Lab Report submissions are due by 10:00 pm on the due dates. Late penalties are applied as a 5% deduction for submissions less than 24 hours late or with a penalty of a 10% deduction per day late thereafter.

Non-Embedded Project Overview (Lab A)

A closed, non-embedded project is to be done by all students taking the ECE-298 course. This project will lead the class into basic schematic concepts and instruction of how to use the Proteus EDA platform tools for later schematic entry, schematic simulations, and Printed Circuit Board (PCB) design.

The deliverable for Lab A will be a PCB assembly that must be soldered, debugged by each student.

Embedded Project Overview (Labs Bx)



You will also be developing a partially-open, embedded design that uses a processor, sensors, actuators, and user I/O that can execute an automated function for the course Embedded project.

You will develop the design in two phases:
1) Feasibility Model Phase
2) Prototype Model Phase

In the **Feasibility Phase** we will explore the capabilities of the sensors, actuators and MCU interfaces for the Embedded project. This phase aims to:

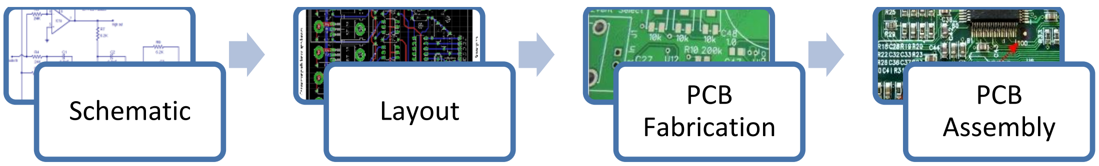
1) establish how these devices function based on information from their respective datasheets.
2) develop hardware interfaces to control and observe the device signals used with the MCU.
3) Measure and test, under operation by the MCU, these interfaces on a breadboard platform with signal voltage/current/power aspects. This information will be recorded and incorporated into a Feasibility Model Design Review video.
4) developing the embedded MCU to <u>run all circuit interfaces simultaneously</u> for the Embedded project operation. This will be evaluated later in a Final Demo for each Team's Embedded Project solution

Then, with the **Feasibility Phase** completed and understood, the **Prototype Phase** develops the design further by:

1) developing the design towards becoming a PCB Assembly. Part Placement and their connections (established in the Feasibility phase) are used to create a PCB design and support files (Gerber files, Bill of Materials). The design details will be submitted for the Prototype Model Report.

General Hardware Development Overview

Many students have ample opportunities to develop software, but this course is often a student's first proper hardware development introduction. Projects that include hardware development often go through rigorous prototyping phases since hardware must work as delivered and is very costly to fix afterward, unlike software, which can be patched and updated. For large projects, there may be many iterations of prototyping before a product is finally "production ready".



We are using Electronics Design Automation (EDA) software called **Proteus** to create a **schematic** and a **layout** for the embedded project. The **schematic** is a circuit diagram that shows how components are connected (like a circuit diagram from ECE 140 or 240). This schematic tells the EDA software how you want the components to be electrically connected. The **layout** is a CAD drawing that specifies where components will be placed on the PCB (placement) and how they will be physically connected with copper wires (routing). The schematic and layout undergo automated testing to check for errors, much like debugging code in a compiler.

In a real-world project, the Layouts are sent to a **PCB fabrication** facility ("fab"). When the "PCB's" arrive, the components are soldered onto the PCB that creates a **PCB assembly** (PCBA). Then, the PCBA would be tested on its own for any process faults such as solder shorts etc. Passing these early tests leads to the integration of the PCBA onto the Nucleo Development Board. Further testing and debugging on this integrated assembly then determine, if another prototyping round (schematic corrections, new layout, PCB fab and PCBA) is required to meet your project requirements.

For this course, the PCB Assembly (PCBA) experience is covered in the LAB A sessions for logistics reasons.

Notes and Policies

The following statements are a required part of every course outline.

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 here for more information.

Grievances

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 Section 4 of Policy 70, Student Petitions and Grievances. When in doubt please be certain to contact the departments 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. 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 are grounds. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals.

Note for Students with Disabilities

The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, 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 the OPD at the beginning of each academic term.

Fair Contingencies for Emergency Remote Teaching.

We are facing unusual and challenging times. The course outline presents the instructor's intentions for course assessments, their weights, and due dates. As best as possible, we will keep to the specified assessments, weights, and dates. To provide contingency for unforeseen circumstances, the instructor reserves the right to modify course topics and/or assessments and/or weight and/or deadlines with due and fair notice to students. In the event of such challenges, the instructor will work with the Department/Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty.

In the event of such a contingency being required, the course will switch to an asynchronous form of content delivery. This means that the Lab Presentations will be posted online at an appropriate time, and they can be viewed by the students at any time after the posting. There will be additional online Q&A sessions added to the schedule to cover any queries from the class.