ECE 298 – Instrumentation and Prototyping Laboratory Course Outline

F2021

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 CLOSED-ENDED design (one that is fixed in function and can't be changed) as the first project (it is non-embedded….no CPU/MCU). All students taking the course will be divided into "ONLINE" students and IN-PERSON" students. The purpose of this first project will be the following:

1) All students begin to use the Proteus electronic design platform to complete a schematic and learn how to perform simulations to analyse the design's behaviour.
2) IN-PERSON students will be receiving kits to build a PCB assembly of a design and use instruments in the LAB to debug and then demonstrate it to the teaching team near the end of the term. Students will work in teams of two.
3) ONLINE students will be given the same starting project as the in-person group but will be challenged to enhance its capability and verify it with Proteus simulation. This will also be due near the end of the term. Students will work in teams of two.

After this project is disclosed to the students during the first lab session, the ONLINE students will be supported online by the teaching staff. For the IN-PERSON students, a schedule will be setup for access to the FYDP Lab (E2-3353 to practice soldering skills and to build and debug the PCB assembly for demonstration.

This course will also focus on developing an OPEN-ENDED solution to a stated problem for the term for **all students**. This second project will begin in the second Lab session for this purpose. The solution must be an embedded system on a prescribed platform (STMicro NUCLEO64-F401RE). Students will work in teams of two through a feasibility model and prototype development cycle. Students will submit parts of their projects during the course and provide technical documentation as though their project will be assigned to an incoming co-op student.

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 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*, 3^{nd} Ed., Prentice-Hall, 2015. ISBN-10: 0521809266. ISBN-13: 978-0521809269

Grading

All grade items, marking rubrics, and guidelines will be available on LEARN.

Course Deliverable	Dates	Weight
Lab A – CLOSED-ENDED Digital Timer Project (non-embedded - all student teams) IN-PERSON Teams DEMO Lab A Kit in Nov. ONINE TEAMS submit Lab A report by Nov 29th	Developed along the term	20%
Lab B1 –OPEN Embedded Project – Feasibility Phase 1 (all student teams) Explore Proteus devices for implementing sensors and actuators for the project. LAB B1 Report Required	Sept 21 – Oct 4	10%
Lab B2 – OPEN Embedded Project -- Feasibility Phase 2 (all student teams) Developing the electrically interfaces for each sensor/etc. to MCU pins. Developing how the MCU pins exercise the circuit interfaces. LAB B2 Report Required	Oct 5 – Oct 25	10%
Lab B3 – OPEN Embedded Project -- Prototype Phase 1 (all student teams) Developing the MCU executable code to operate all circuits simultaneously. LAB B3 Report Required	Oct 26 -Nov 8	10%
Lab B4 – OPEN Embedded Project -- Prototype Phase 2 (all student teams) How do we design a PCB to make a circuit assembly from the schematic? LAB B4 Report Required	Nov 9 – Nov 22	10%
Four LAB Quizzes	Due on **<u>Lab Bx due dates</u>**	40% (10% each)

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.

F2021 ECE-298 LABS SCHEDULE					Comments
SEPTEMBER	M T W Th F 1 2 3	M T W Th F 6 7 8 9 10 **1**	M T W Th F 13 14 15 16 17 **2**	M T W Th F 20 21 22 23 24 **3**	Teams chosen Sept 13; LAB A STARTS Sept 14; LAB B1 starts Sept 21;
				LAB A Work	
		F2021 starts; TEAMS Chosen	**LAB A Non-Embedded Project**	**LAB B1 - Embedded Project FEASIBILITY PHASE 1**	
SEPT/OCT	27 28 29 30 1 **4**	4 5 6 7 8 **5**	11 12 13 14 15 **6**	18 19 20 21 22 **7**	LAB B1 REPORT DUE Oct. 4; LAB B2 starts Oct 5;
	LAB A Work				
	LAB B1 - FEASIBILITY PHASE 1	**LAB B2 FEASIBILITY PHASE 2**	**READING WEEK**	**LAB B2 FEASIBILITY PHASE 2**	
OCT/NOV	25 26 27 28 29 **8**	1 2 3 4 5 **9**	8 9 10 11 12 **10**	15 16 17 18 19 **11**	LAB B2 REPORT DUE Oct. 25; LAB B3 starts Oct. 26; LAB A IN_PERSON TEAM DEMOS BEGIN; LAB B3 REPORT DUE Nov. 8; LAB B4 starts Nov. 9;
	LAB A Work		**LAB A IN-PERSON TEAM DEMO's**		
	LAB B3 PROTOTYPE PHASE 1		**LAB B4 PROTOTYPE PHASE 2**		
NOV/DEC	22 23 24 25 26 **12**	29 30 1 2 3 **13**	6 7 8 9 10 **14**		LAB B4 REPORT DUE Nov 22; LAB A IN_PERSON TEAM DEMOS COMPLETED; LAB A REPORTS (ONLINE Teams) DUE by Nov 29
	LAB A DEMO's Completed by IN-PERSON TEAMS	**LAB A REPORTs SUBMITTED by ONLINE STUDENTS**	**F2021 Term ends**		

Lab Overviews

Each lab will kick off with synchronous and recorded presentations, offered on MS Teams. The synchronous presentations will be given on the **first TUESDAY and WEDNESDAY evenings (7-9pm EST)** of a LAB development cycle. The instructor will go over the lab procedures and expectations and answer live questions.

IN-Person and ONLINE students will each be able to examine the functionality of their circuit designs by using Lab instruments (Proteus Virtual Lab Instruments for IN-Person and ONLINE students; FYDP Lab Instruments for IN-Person students) to observe signal activity and determine their design's functional progress.

Embedded Project Lab (LAB Bx) Due Dates

Group submissions drop boxes are set up for each lab with the due dates applied. Lab submissions are due at 4:30 pm on the dates prescribed. Late penalties are applied as a 5% deduction for < 24 hours late with an additional 10% deduction per day late thereafter.

Quizzes

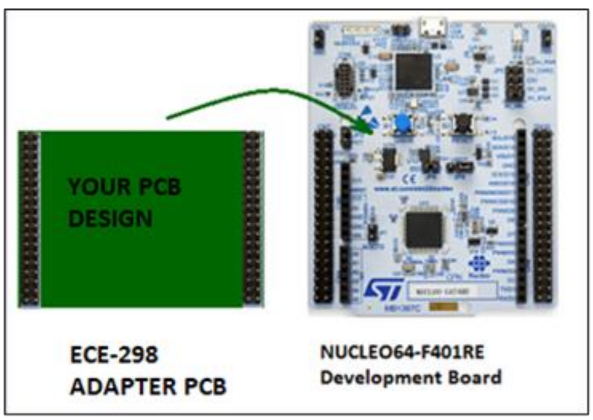
Your experiences working through the lab materials and completing the lab deliverables are all the studying you need for the four lab quizzes. The quizzes are available **24 hours before and after the deadline**. The quiz answer will become available for review 24 hours after the deadline.

Course CLOSED, 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 schematic concepts and instruction of how to use the Proteus platform tools for schematic entry and schematic simulations. After this, because of course logistics, there will be two different paths for this lab project development. One for online students and one for in-person students.

The deliverable for online students for Lab A will be due near the end of the term (see Learn). The deliverable for the in-person students for Lab A will be a PCB assembly that must be soldered, debugged, and demonstrated in the FYDP Lab by the end of the term. A schedule for this will be posted on Learn.

Course OPEN ended, Embedded Project Overview (Labs Bx)



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

You will develop the design in two phases:
1) Feasibility Model Phase (Labs B1 and B2)
2) Prototype Model Phase (Labs B3 and B4)

LEARN has detailed information on these phases.

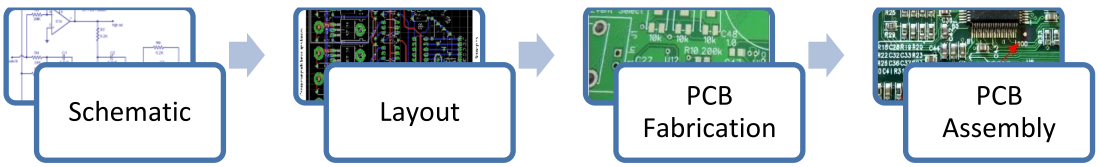
The **Feasibility Phase** will explore the kinds of sensors and actuators for the project. This phase aims to learn how these devices function and develop hardware interfaces to control and observe their interface signals to a hypothetical 3.3V MCU. During this phase, students will also begin to learn some aspects of MCU code development tools. Each individual hardware interface will be tested, in isolation, for operation by the MCU.

With the Feasibility Phase completed and understood, the **Prototype Phase** develops the design further by developing the embedded MCU to run all circuit interfaces simultaneously. During this phase (in Lab B4), the design must also be migrated to real-world parts (as opposed to virtual parts) that can be acquired for building your design into an assembly. The parts are to be arranged and connected on a Printed Circuit Board (PCB) that you will design.

For each of the Embedded Project labs, you will submit project deliverables that may include code, schematics, layouts, and documentation in drop boxes on LEARN. Template files provide a starting point for each lab on LEARN and can be modified to suit your project.

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**. 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).

At this point, 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 determines if another prototyping round (schematic corrections, new layout, PCB fab and PCBA) is required to meet your project requirements.

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.