ELEC4601 – Microprocessor Systems

Professor: Dr. MacEachern, 7044MC, leonard.maceachern@carleton.ca

Course Description:

Interfacing aspects in microprocessor systems. Microprocessors and bus structures, internal architecture, instruction set and pin functions. Memory interfacing, input-output, interrupts, direct memory accesses, special processors and multiprocessor systems. Precludes additional credit for SYSC 3601 and COMP 3006.

Prerequisite: ELEC 2607 and one of SYSC 2003 or SYSC 3003 or SYSC 3006 or permission of the Department.

Schedule:

There are two lectures per week and three hours of laboratory work each alternate week. The day-by-day schedule is given on **the cuLearn site, which will be available on the first day of lectures**.

Textbook:

There is no mandatory textbook for the course. Data sheets, manuals, and other freely available resources will be posted on cuLearn as the course progresses, as required. Other sources of relevant information such as freely available on-line videos, blogs, and websites will be recommended as the term progresses. Some book recommendations will also appear on cuLearn as we progress through the course, but any required material will be provided to the class.

Teaching Assistants:

The teaching assistants this term[1] are:

Name	Email
Dusan	dusangostimirovic@cmail.carleton.ca
Soroush	soroushsheikhpourkou@cmail.carleton.ca
Kareem	kareemelgably@cmail.carleton.ca
TBD	TBD

Office Hours:

All office hours (TA hours and Professor hours) will be posted on cuLearn. We will adjust our availability depending on demand throughout the term, for example, prior to the midterm. Due to COVID-19, all office hours will be held via video conferencing software, such as FaceTime, Zoom, or Microsoft Teams.

[1] These TAs are proposed. No one has been confirmed at the time of this writing (Sept. 1/20).

Learning outcomes[2]:

Microprocessor systems are used in all aspects of modern devices in several fields such as automotive systems, medical devices, wearable devices, and industrial measurement and control systems. This course establishes solid conceptual background that enables students to design, develop, test, debug, and analyze different microprocessor systems ranging from the conventional x86 processors to microcontrollers/embedded processors and advanced multi-core/networked processors. The learning outcomes of this course can be described as follows:

1. Microprocessor System Architecture
   - Describing basic building blocks of a microprocessor system (Knowledge outcome)
   - Explaining the architectures of microprocessor systems (Knowledge outcome)
   - Explaining instruction sets and instruction groups (Knowledge outcome)
   - Explaining basic instruction execution cycle and timing (Knowledge outcome)
   - Understanding of advanced computing schemes such as pipelining (Knowledge outcome)
   - Distinguish the merits/limitations of RISC and CISC Architectures (Knowledge outcome)

2. Bus and Clocks
   - Defining the role of clocks in synchronizing instructions operations (Knowledge outcome)
   - Defining the function and types of buses (Knowledge outcome)
   - Drawing a bus timing diagram for common I/O operations (Skills outcome)
   - Calculating critical timing parameters of common I/O operations (Skills outcome)
   - Listing potential timing errors/hazards associated with I/O operations (Skills outcome)

3. Input/output
   - Describing different types of interfacing (serial/parallel) (Knowledge outcome)
   - Describing and implementing I/O devices handling mechanisms (Skills outcome)
   - Describing interrupts and implementing interrupts service routines (Skills outcome)

4. Memory
   - Describing different types and usages of memory (Knowledge outcome)
   - Explaining addressing modes (Knowledge outcome)
   - Describing memory allocation mechanisms (Knowledge outcome)

5. Software and Programming
   - Understanding how program instructions are executed (Knowledge outcome)
   - Tracing the execution of assembly code programs (Skills outcome)
   - Diagnosing and correcting (debug) programming errors (Skills outcome)

6. Microcontrollers
   - Applying the taught concepts to microcontrollers (Knowledge outcome)
   - Describing ARM microprocessor architecture/programming model (Knowledge outcome)
   - Developing programs (in assembler/C) for microcontrollers systems (Skills outcome)
   - Utilizing microcontroller timers/peripherals to interface with sensors (Skills outcome)
   - Explaining and using microcontrollers Analog to Digital conversion (Knowledge/Skills)

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[2] These learning outcomes were originally formulated by Dr. Atia, who taught the course in 2018. I continued with these goals in 2019, and I am continuing with these goals in 2020 for consistency and because they are great outcomes!

- Explaining multi-core microprocessor systems and architectures (Knowledge outcome)
- Understating parallel and distributed processing mechanisms (Knowledge outcome)
- Implementing networked microprocessor systems (Knowledge and skills outcome)

Lecture Plan:
A draft of the lecture plan is given below. I will make materials available to the class on cuLearn. The flow of the course will be as below, with some variation depending on interests and circumstances. Topic 22 will be offered if time permits.

Topic	Lecture Topics (will adjust as needed and time permits)	Related Lab
1	Introduction, basic architecture, and instruction execution cycle	
2	Instruction Set Architecture (ISA) and introduction to x86 Assembly	
3	x86 Assembly and Addressing Modes	
4	Basic Input/output and interfacing concepts	Lab 1
5	x86 Interrupts	Lab 1
6	Buses and Timing Hazard	
7	Embedded Processors, ARM processors, and Cortex-M4 Processor	
8	Cortex-M4 Programming	Lab 2
9	Cortex-M4 Interrupts	Lab 2
10	Memory Organization and Cache Memory Concepts	
11	Cortex-M4 Memory Map and Bit-band operations	Lab 3
12	Review Lecture 1 for Midterm	Lab 3
13	Midterm Exam	
14	Pipelining, RISC vs. CISC, Superscalar Computers	
15	Analog Digital Conversion	Lab 4
16	Timers and Pulse Width Modulators	Lab 4
17	I2C and SPI Interfacing Protocols	
18	Networks and Networked Microprocessor Systems	
19	Digital Signal Processors (DSP) and Floating Point Units (FPU)	Lab 5
20	Cortex-M4 DSP and Fractional Arithmetic Features	Lab 5
21	Parallelism and Multi-core Systems	
22	Graphical Processing Units (GPU) and GPU-CPU computing	
23	Review Lecture 2 for Final	
24	Reserved	

Course Content Delivery:
The basic plan for course content delivery is a "blended" approach. The course slides and any related video material will be made available a few days prior to each lecture. The official lecture time will be used *as needed* to answer any questions related to the previously posted course contents. Material presented during the question and answer sessions will be recorded and posted following the sessions. Student anonymity will be respected if requested.

Student Evaluation:
The marking scheme this term is:

Deliverable	Percentage	Comments
Laboratories	25%	Five labs, 5% each.
Midterm	25%	Cannot be transferred to final exam mark. Partially take-home and partially a timed test on cuLearn.
Final Exam	50%	Must pass (50% is a pass) to pass the course. Partially take-home and partially a timed exam on cuLearn.

Laboratory Information:
A major component of this course is the "hands-on" hardware lab experience with microprocessor systems, including the use of test and measurement equipment. Due to COVID-19, the first two labs will be partly conducted by Dr. MacEachern and the corresponding videos and data will be posted for the students to use in order to answer related questions. Some portions of the first two labs can be performed remotely, and the students will be responsible for those portions fully.

For the final three labs, the equipment is accessible remotely and students will work in small groups and access the test and measurement equipment, and development environment, using Remote Desktop through Carleton's VPN.

Prior to the first lab we will segment the class into small lab groups. Each group must submit their joint lab report for each lab electronically through cuLearn. The mandatory lab report format will be posted to cuLearn.

Additional Information:
The course site on cuLearn will contain important course updates and information throughout the term, so please consult the site regularly.

General Regulations
Attendance: Students are expected to attend all required lectures and lab periods[3]. The University requires students to have a conflict-free timetable. For more information, see the current Undergraduate Calendar, Academic Regulations of the University, Section 1.2, Course Selection and Registration and Section 1.5, Deregistration.

[3] Your attendance is required for scheduled labs. For lectures, I'll let you know in advance if you must attend a video lecture.

Health and Safety: Every student should have a copy of our Health and Safety Manual. A PDF copy of this manual is available online: http://sce.carleton.ca/courses/health-and-safety.pdf

Deferred Term Work: Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases this must occur no later than three (3.0) working days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule. For more information, see the current Undergraduate Calendar, Academic Regulations of the University, Section 2.6, Deferred Term Work.

Appeal of Grades : The processes for dealing with questions or concerns regarding grades assigned during the term and final grades is described in the Undergraduate Calendar, Academic Regulations of the University, Section 2.7, Informal Appeal of Grade and Section 2.8, Formal Appeal of Grade.

Academic Integrity: Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: https://carleton.ca/registrar/academic- integrity/. This site also contains a link to the complete Academic Integrity Policy that was approved by the University's Senate.

Plagiarism: Plagiarism (copying and handing in for credit someone else's work) is a serious instructional offence that will not be tolerated.

Academic Accommodation: You may need special arrangements to meet your academic obligations during the term. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://www.carleton.ca/equity/

For an accommodation request, the processes are as follows:

- Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see: https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf

- Religious obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see: https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf

- Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult https://carleton.ca/pmc/students/dates-and-deadlines/ for the deadline to request accommodations for the formally-scheduled exam (if applicable).

- Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are

supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/sexual-violence- support/.

- Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see:
https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf