Department of Electronics
Faculty of Engineering, Carleton University,
Ottawa, Canada.

ELEC 4601 [0.5 credit]
Switching Circuits

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 **CMP 3006.**
Prerequisite: **ELEC 2607** and one of **SYSC 2003** or **SYSC 3003** or **SYSC 3006**.

Specific Goals - Student Learning Objectives

Microprocessor systems are used in all aspects of modern life such as home appliances, communication systems, automotive systems, medical devices, wearable devices, and industrial automation. 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. The learning outcomes of this course can be briefed as follows[1]:

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)

1. These learning outcomes were originally formulated by Prof. Atia, (2018) and Prof. MacEachern continued with these goals (2019-2021).

- 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)
   - 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 Brightspace. 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	

Resources

- Course Brightspace site
- Designing Embedded Hardware, 2nd Edition, John Catsoulis, 2005.
- Microprocessor Theory and Applications with 68000/68020 and Pentium, M. Rafiquzzaman, 2008.
- The x86 Microprocessors: 8086 to Pentium, Multicores, Atom and the 8051 Microcontroller, 2nd Edition, Lyla B. Das, 2014.
- The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors, 3rd Edition, Joseph Yiu, 2013.
- Structured computer organization by Tanenbaum, Andrew S, 6th ed, 2013.
- Programming massively parallel processors: a hands-on approach by Kirk, David; Hwu, Wen-mei, 2016.

The course grade will be evaluated as follows:

Method of Evaluation	% of Final Grade	Due Dates*
Lab Assignments	25	lab days
Midterm Exam (Individual)	25	After week 6
Final Exam (Individual)	50	TBA

Notes:

- The exams are for evaluation purposes only and will not be returned to the student.
- Health and Safety: See https://carleton.ca/ehs/programs/working-lab/laboratory-health-and-safety/ for general guidelines.

Satisfactory term work

- In order to pass the course students must achieve *satisfactory performance* during the term.
- Satisfactory performance during the term requires completion of all lab experiments with a combined average grade of >30% on lab reports.
- The final exam must be completed with a minimum grade of 40% to pass the course.

Instructor information

- Name: Arash Ahmadi
- Office: Mackenzie Building 5146
- Office Hours: by email appointment
- Office Phone Number: 613-520-2600 ext. 4451
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Graduate Assistant (GA) information (TBA)

	Name	**Email**	**Office Hours (by appointment)**
1	Arka Singh	ARKASINGH@cmail.carleton.ca	
2	Vrajesh Patel	VRAJESHNIMESHKUMARP@cmail.carleton.ca	
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4	Mahshid Rajati	MahshidRajati@cmail.carleton.ca	

Class and lab information

- Class Location: **Minto Centre 5050**
- Class Time: **1:05 PM - 2:25 PM Wednesday and Friday**
- Lab Time: refer to your schedule
- Pre-requisites, from the current Carleton University Undergraduate Calendars (https://calendar.carleton.ca/undergrad/courses/ELEC/).

General Regulations

- *Online Requirements*: Due to content currently being provided in an online capacity, students are required to have a stable and reliable internet connection.

- *Copyright on Course Materials*: The materials created for this course (including the course outline and any slides, notes, program source code, labs, projects, assignments, quizzes, exams and solutions) are intended for personal use and may not be reproduced or redistributed or posted on any website without prior written permission from the author(s).

- *Attendance*: Students are expected to attend all lectures and lab periods. 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.

- *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. Since students are required to have a stable and reliable internet connection, a poor internet connection will not be considered a sufficient reason to defer an online exam.

- *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 offense 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/

Intellectual Property

Lectures and course materials prepared by the instructor are considered to be an instructor's intellectual property covered by the Copyright Act, RSC 1985, c C-42. These materials are made available to you for your own study purposes and cannot be shared outside of the class or "published" in any way. Lectures, whether in person or online, cannot be recorded without the instructor's permission. Posting course materials or any recordings you may make to other websites without the express permission of the instructor may constitute copyright infringement.

Classroom Conduct

- The classroom environment is premised on commitment to the following:
  - Professionalism
  - Respect
  - Honesty
  - Privacy

- In the context of online/in-person learning, students are expected to:
  - Represent themselves honestly in all communications, applications, assignments, tests, examinations, and other correspondence.
  - Respect the need of others to work in an environment that is conducive to learning in an online setting.
  - Be courteous and polite in all electronic exchanges with instructor and fellow classmates.
  - Be active and engaged participants in the learning process.
  - Respect the personal information and privacy of others.
  - Respect all copyright laws.

- While participating in this online/in-person course, students are encouraged to engage in appropriate behaviors. Inappropriate behaviors may include:
  - Using email or login account information that is not your own.
  - Engaging in any behavior that may be disruptive to other learners in the online learning environment.
  - Writing, using, sending, downloading, or displaying any information that is hostile, insulting to others, derogatory, obscene, harassing, threatening or otherwise offensive.
  - Reproducing course content or reposting course materials without explicit permission.