Carleton University — Department of Electronics

Fall 2025

ELEC 2607: Switching Circuits

Introduction

This course aims to introduce students to the theory and hardware/software tools for designing and analyzing combinational/sequential digital circuits and finite-state machines. Lectures cover the basic theory of digital circuits and problem-solving, while Laboratory experiments reinforce the theoretical concepts and provide the design skills using CAD tools, HDL, and FPGA.

Course Description and Requirements

Digital systems, binary numbers, Boolean algebra, logic gates, gate-level minimization, combinatorial circuits, logic circuit modeling and simulation, programmable Logic devices. Flip-flops, latches, sequential circuits, state graphs and state minimization. Counters, registers, and memory. Hazards. Asynchronous sequential circuits, race free assignment, realization.
Includes: Experiential Learning Activity Precludes additional credit for SYSC 2310
Prerequisite(s): PHYS 1004 or PHYS 1002 and second-year status in Engineering
Lectures: three hours a week
Laboratory: three hours alternate weeks.

Instructor

Professor Maitham Shams, Room ME4156
Email: MaithamShams@cunet.carleton.ca
Course Webpage: on Brightspace

Textbook

1) Lecture notes are provided on Brightspace

2) Recommended but not necessary textbook: M Morris Mano, Michael D. Ciletti. "Digital design: with an introduction to the Verilog HDL, VHDL, and system Verilog" Pearson, 2017. Costs around $250.

Lecture Outline

In person, Mondays and Wednesdays & Friday, 10:05-11:25, ME3356
The following topics will be covered during the course lectures with an approximate schedule.

Week 1: Introduction to Digital Circuits
Week 2: Digital logic gates
Week 3: Boolean algebra
Week 4: Binary number system
Weeks 5-6: Hardware Description Language (HDL)

Week 7: De Morgan's theorems and applications
Week 8: Karnaugh maps, function simplification
Week 9: Sequential circuits, latches and flip-flops
Week 10: Finite State Machines
Week 11: Implementation, array logic and MUX
Week 12: State reduction, course overview

Laboratory and Problem Analysis Sessions

3 hours alternate weeks as per schedule and location posted on Brightspace.

- There are five labs as follows:
  - Lab 1: Digital Logic Circuit Modeling and Simulation with Multisim
  - Lab 2: Seven Segment Display and FPGA
  - Lab 3: Adder/Subtractor Circuit
  - Lab 4: T-Bird Tail-Light Control
  - Lab 5: Double Sequence Detector

- Labs are 3 hours in duration and will be held in ME4275. Labs and PA sessions usually "alternate" from week to week and will be held according to the schedule shown on the course module in Brightspace. You must attend your lab in the session you are registered. Changing sessions is not allowed without the head TA's permission.

- If for some reason a Lab needs to be rescheduled OR a Lab falls on one of the University holidays, students in those sections must try to rearrange their schedule to make up the lab in another of the regularly scheduled lab sessions, as arranged by the instructor.

- Attend each lab punctually. Be prepared for the lab experiment by reading the lab instruction sheets before entering the lab. Some labs have a pre-lab exercise that must be submitted by the due dates specified on Brightspce.. You are not permitted to do the lab unless the prelab is completed. The TA will check that the the pre-lab has been completed.

- Labs are performed in groups of two. A lab report should be submitted online for each lab by every group. Report due dates are stated on Brightspace.

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows.

- Quizzes 15% pop-up in class
- Assignments 0% not marked
- Labs 20%
- Midterm Exam 20% on Thursday, date and location are announced on Brightspace, class time, closed book
- Final Exam 45% closed book

Important Notes.

- Lab exemptions cannot be granted due to accreditation requirements.

- Students are required to complete all lab sessions and must achieve a minimum of 50% in their overall lab marks to pass the course. Missing even one lab will fail the course.
- To pass the course, students must obtain at least 50% in their term mark (which includes labs, assignments, and the midterm) and a minimum of 50% on the final examination.
- Final exam papers will not be returned to students.

Learning Outcomes

A student who successfully fulfills the course requirements will have demonstrated the following knowledge and skills.

1. Define the binary system and 2's complement representation
2. Apply operations such as addition and subtraction for binary numbers and 2's complement notation
3. Comprehend the different theorems in Boolean algebra and apply them for logic functions
4. Design logic circuits implementing a Boolean expression
5. Define Karnaugh maps for Boolean functions and perform algorithmic reduction on them
6. Define combinational circuits such as exclusive-ORs, exclusive-NORs, (de)multiplexers and adders
7. Design programmable array logic (PAL) components to implement logic functions
8. Define sequential circuits such as latches and flip-flops
9. Design synchronous and asynchronous finite-state machines from functional specifications
10. Design and synthesize digital circuits using HDL (Verilog)
11. Reduce number of states in finite-state machines
12. Define Mealy and Moore output FSM circuits
13. Use Multisim, construct and test digital circuits with a lab-partner
14. Use computer-aided tools in a lab-environment with a lab-partner to design, construct, simulate and test digital circuits
15. Write lab-reports, answer essay-type questions using text, equations and numeric values for assignments and examinations

Graduate Attributes

An institution must demonstrate that graduates of its programs possess the attributes described below. In addition, the institution must implement and employ processes to demonstrate that program outcomes are being assessed in the context of these attributes, and that the results of such assessments will be applied to the further development of programs. The graduate attributes are:

1. A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

2. Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

3. Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

4. Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and

societal considerations.
5. Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7. Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9. Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10. Ethics and equity: An ability to apply professional ethics, accountability, and equity.
11. Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.

12. Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

This course (ELEC 2607) will score the following graduate attributes.
1.10.E - Knowledge base: Discipline-specific concept DOE-7: Digital systems and computers
2.1 - Problem analysis: Problem definition
2.2 - Problem analysis: Approach to the problem
2.3 - Problem analysis: Use of assumptions
2.4 - Problem analysis: Interpreting the solution - validity of results
3.1 - Investigation: Complex problem assessment
3.2 - Investigation: Design of experiment
3.3 - Investigation: Experimental procedure
3.4 - Investigation: Data reduction methods and results
3.5 - Investigation: Interpretation of data (synthesis) and discussion
4.1 - Design: Clear design goals
4.2 - Design: Detailed design specifications and requirements
4.4 - Design: Design solution(s)
4.5 - Design: Design implementation / task(s) definition
4.6 - Design: Alternate solution(s) definition
4.7 - Design: Evaluation based on engineering principles

They are scored through the responses provided in pre-lab and lab reports, assignments, and midterm and final exams. The graduate attribute scores may in some cases be derived from graded material, however the graduate attribute scores are not used in determination of the final grade for the course.