Purdue University, Department of Computer Science

Syllabus – CS 25000 Computer Architecture

by George Adams

2018 Spring

Course Objectives

This course introduces you to the operation, design, and analysis of hardware computing platforms. This course requires knowledge in C programming.

The topics covered include: fundamentals of computing hardware; digital logic circuits; device technologies and technology trends; combinatorial and sequential circuits; clocks; registers; data representation; basic computer arithmetic; arithmetic-logic units; instruction sets; RISC and CISC designs; assembly language; Von-Neumann and Harvard architecture; instruction execution pipelines; code scheduling; caches and memory organization; physical and virtual memory; page tables; DMA; bus architecture; polling and interrupts; memory-mapped I/O; parallelism; power; advanced topics.

Course Outcomes

A student who fulfills the course requirements will

1. understand the fundamentals of computing hardware, digital logic circuits, and data representation
2. understand processors including the central processing unit (CPU), instruction sets, and assembly language
3. understand physical and virtual memory systems, memory technologies, memory organization, and caching
4. understand input output mechanisms including the interconnection of computers and external devices, buses, and device drivers
5. understand advanced aspects of architecture including parallelism and power management

Semester Schedule (take as a general indication; subject to modification)

Week 1
Lecture: Introduction; historical computing examples; technology trends; fundamental topics in computer architecture; use of abstraction; analog versus digital representation of information; Boolean logic; truth tables; the voltage divider.
Lab 1: Safety instruction, lab safety quiz, and subsequent lab kit distribution; lab kit familiarization and inventory; initialization of Raspberry Pi software environment.
Reading: Chapters 1 and 2

Week 2
Lecture: Logic circuits; SOP and POS Boolean forms; Karnaugh Maps; binary addition and adder circuits; feedback and memory; SR latch
Lab 2: Logic gates and logic circuit design; use of the breadboard.
Reading:

Week 3

Lecture: Sequential circuits; decoders; multiplexers; counters; representation of characters and numbers; big and little endian; below the program; information representation; number systems for integers and floating point; characteristics of a computing platform; uses of abstraction.
Lab 3: Building an adder or similar complexity combinatorial logic circuit from gates.

Week 4
Lecture: Fundamentals of Boolean logic; the nature of digital devices; gates, truth tables, logic equations, combinatorial logic; clocks; memory elements; sequential circuits and finite state machines.
Lab 4: S'R' latch, sequential circuit operation, de-bouncing inputs.

Week 5
Lecture: Machine instructions: the control flow model of computation; instruction representation; operand addressing; instruction types; computer arithmetic; instruction sets.
Midterm #1

Week 6
Lecture: Assembly language; programming paradigm; assemblers. History and trends.
Lab 5: Introduction to the Raspbian Linux environment and programming and debugging on the Raspberry Pi; probing for basic architectural characteristics (big/little endian); memory dump analysis.

Week 7
Lecture: Processors: data paths; pipelined execution; vertical and horizontal microcode, endian storage order.
Lab 6: Calling assembly from C and calling C from assembly. Compiling C programs into assembly.

Week 8
Lecture: Memory and storage technologies (SRAM, RAM, Flash, ROM, etc.) and basic organization, caching and caches. History and trends.
Lab 7: Memory allocation and stack mechanism in assembly programs

Week 9
Lecture: Virtual memory, page faults, TLB.
Lab 8: Row-major and column-major array storage.

Week 10
Lecture: Input / Output concepts and terminology; programmed and interrupt-driven I/O; buffered I/O.
Midterm #2
Lab 9: Comparing un-buffered and buffered I/O (due in two weeks because of midterm).

Week 11
Lecture: Exception and interrupt handling. Lab: Exception handlers. Long jumps. 13. I/O. Bus. I/O and network interface.
Lab continues from previous week.

Week 12
Lecture: Performance; Amdahl's Law; examples.
Lab 10: Various assembly language programming, Raspberry Pi architectural exploration, and hardware interface experiences (implement a variadic function using the stack; write a hex dump using assembly; use general purpose I/O pins on Raspberry Pi to perform Internet of Things-type actions (hue and intensity control of LED lighting, process sensor data, etc.); examine low level ARM processor

performance monitors and behavioral controls).

Week 13
Lecture: Parallelism; data pipelining; multicore; multiprocessing; Flynn's taxonomy; operation of SIMD architecture; MIMD coordination via mutual exclusion.
Lab 11: Various, see description with Lab 10.

Week 14
Lecture: Power and energy considerations; real-life examples.
Lab 12: Various, see description with Lab 10.

Week 15
Lecture: Instructor-selected advanced topics and review for final exam.
Lab: no lab assignment (Dead Week).

Exams	Time	Location	Date of omitted lecture
Midterm 1	Tuesday, Feb. 06 from 6:30pm to 7:30pm	LE2 in PHYS 114 LE1 in FRNY G140	Wednesday, Feb.07
Midterm 2	Tuesday, Mar. 27 from 6:30pm to 7:30pm	LE2 in PHYS 114 LE1 in FRNY G140	Wednesday, Mar. 28
Final	Wednesday, May 02 from 10:30am to 12:30pm	Loeb Playhouse (STEW 183) for both LE1 and LE2	none

Office Hours

Instructor	Hours	Location
George Adams	MWF 12:20pm-1:15pm	WTHR 172 (after LE2)
George Adams	MW 3:20pm-3:45pm	WTHR 172 (after LE1)
George Adams	MW 4:00pm-5:45pm	HAAS 122
George Adams	R 3:00pm-6:00pm	HAAS 122
George Adams	And by appointment	Request via gba@purdue.edu
Sana Nazir	M 3:00pm-5:00pm	HAAS G50
Sana Nazir	TR 9:00am-11:00am	HAAS G50

Course Personnel

Graduate Teaching Assistants (GTAs)
- Ishan Chawla chawla7@purdue.edu
- Sana Nazir snazir@purdue.edu

- Liliane Ntaganda lntagand@purdue.edu
- Lakshmi Prakash lprakash@purdue.edu
- Animesh Sinha sinha39@purdue.edu
- Zixun Yu yu645@purdue.edu

Undergraduate Teaching Assistants (UTAs)

- Adhishree Abhyankar, Yanal Abusamen, Kailasam Ayalur Sriram, Aaron Bienz, Abhijeet Chakrabarti, Joey Dafforn, Yilang Fan, Gunjan Gauri, Varun Gupta, Nanxin Jin, Adit Kumar, Krishna Kumar, Weizhi Li, Yaoxi Liang, Brandon Marx, Sripath Mishra, Vihar Patel, William Reed, Samuel Roberts, Jimmy Smagacz, Akshay Srinivasan, Trevor Tang, Xi (Amelie) Yang, Hannah Zentner, Kenny (Yuxin) Zheng

Course Times and Locations (assigned personnel subject to change)

Lecture	Time	Location	Instructor	
LE2 CRN 11332	MWF 11:30am-12:20pm	WTHR 172	George Adams	
LE1 CRN 13005	MWF 2:30pm - 3:20pm	WTHR 172	George Adams	
Lab	Time	Location	GTA	UTAs
01	T 9:30am - 11:20am	LWSN B160	Zixun Yu	Aaron Bienz, Nanxin Jin, Syed Mudabbi, Hanna Zentner
06	T 11:30am - 1:20pm	LWSN B160	Liliane Ntaganda	Aaron Bienz, Varun Gupta, Yaoxi Liang, Samuel Roberts
10	T 1:30pm - 3:20pm	LWSN B160	Lakshmi Prikash	Abhijeet Chakrabarti, Brandon Marx, Sripath Mishra
08	W 1:30pm - 3:20pm	LWSN B160	Liliane Ntaganda	Yanal Abusamen, William Reed, Akshay Srinivasan, Kenny Zheng
05	W 3:30pm - 5:20pm	LWSN B160	Sana Nazir	Joey Dafforn, Jimmy Smagacz, Trevor Tang
11	R 9:30am - 11:20am	LWSN B160	Zixun Yu	Nanxin Jin, Adit Kumar, Krishna Kumar, Hannah Zentner
03	R 11:30am - 1:20pm	LWSN B160	Animesh Sinha	Kailasam Ayalur Sriram, Gunjan Gauri, Yaoxi Liang, Samuel Roberts
07	R 1:30pm - 3:20pm	LWSN B160	Lakshmi Prikash	Yanal Abusamen, Abhijeet Chakrabarti, Vihar Patel, Xi (Amelie) Yang
09	F 9:30am - 11:20am	LWSN B160	Ishan Chawla	Yilang Fan, Nanxin Jin, Weizhi Li

02	F 11:30am - 1:20pm	LWSN B160	Ishan Chawla	Adhishree Abhyankar, Joey Dafforn, Yilang Fan, Kenny Zheng
12	F 1:30pm - 3:20pm	LWSN B160	Animesh Sinha	Yanal Abusamen, Jimmy Smagacz, Akshay Srinivasan, Kenny Zheng

Coursework Weighting
Your course grade is based on in-class iClicker quizzes, homework exercises, laboratory projects, in-class exams, and a final exam. Your letter grade for the semester will be computed using these weights:

- 5% Quizzes (requires iClicker; lowest 4 quiz scores will be dropped)
- 15% Homework (lowest homework score will be dropped)
- 40% Laboratory projects (lowest lab score will be dropped)
- 20% Midterm exams (10% each)
- 20% Final exam

Piazza
We will use Piazza to facilitate discussions for the class. Sign up using the link on the course homepage within Blackboard. You can post public questions visible to the entire class or private questions visible only to the instructors. You may publicly post questions including small snippets of code (using the <code> tag), but do not post extensive pieces of code publicly.

Lab Session Policy and Lab Kits

(1) Attendance in laboratory is required unless there is no lab assignment due in a given week. Students must attend their respective registered lab session. If you will not be able to attend a session, you should notify the TA or the professor prior to that lab session. It may be feasible to arrange participation in another session, earlier or later in the week, but see the Late Policy below.
(2) Typically, you will be assigned a new lab each week that is due by the end of your lab session the following week. For example, if a lab assignment was given to you in a Tuesday lab session, it is due by the beginning of the next same Tuesday lab session.
(3) Lab circuits submitted for grading must, after circuit operation has been evaluated, be disassembled in the presence of the TA.
(4) The first hour of each lab session is reserved for students registered in that session. However, if you wish to ask questions of the TAs or use lab equipment, then you are welcome to attend any lab session during its second hour on a space-available basis and with permission of the graduate teaching assistant in charge.
(5) Your lab kit is yours to keep after the semester ends.

Academic Policies
(0) *Your comments to help improve the course are always welcome.*
(1) **Late Submission of Assignment Policy:** There is zero credit for late assignments. Solutions will be distributed shortly after the due time of each assignment.
(2) **Missed iClicker Quiz Policy:** Make-up iClicker quizzes are not available.
(3) **Regrade Policy:** Requests to re-score homework assignments, lab assignments, or exams should be made within one week after the score is posted in Blackboard.
(4) **Excused Absences:** Excused absence and the opportunity to make up missed classwork is available with written trustworthy third-party documentation of the reason for your absence. Acceptable third parties include your doctor, the Purdue University Office of the Dean of Students, and others. Exclusion

of lowest lab, lowest homework, and lowest four (4) iClicker scores is designed to support your routine needs to be absent or to load-balance CS250 with your other class assignments when no responsible third party can provide a written reason for your absence.
(4) **Academic Honesty:** Course policies are as described at http://spaf.cerias.purdue.edu/cpolicy.html and Departmental Academic Integrity Policy. These policies will be followed unless written exception is provided to you by the course instructor.

- All work graded must be done individually and must be your own effort. You are allowed to interact with others to discuss and obtain help with basic concepts covered in lectures or the textbook, homework specification (but not solution), and program syntax issues (but not program design). However, unless otherwise noted, work turned in needs to reflect your own efforts and knowledge. Sharing or copying solutions is unacceptable. Do not copy code and then make changes (either from the Web or from other students)
- Course instructor and staff will not make efforts to determine the source of copied submitted graded work. All instances of copied graded work will receive the same treatment under this academic honesty policy. Therefore, we recommend that you take precautions to prevent the theft of your work.
- Be aware that we use a software tool called MOSS (http://theory.stanford.edu/~aiken/moss/) to check for copying among submitted assignments. Additionally, the instructor and TAs will be inspecting all submitted material to ensure honesty.
- Penalties
    - A first instance of academic dishonesty will result in a zero for that assignment. A second instance of academic dishonesty will result in a grade of F.
    - In accordance with the Purdue University Department of Computer Science Academic Integrity Policy, any instance of academic dishonesty on an exam, project, or assignment will be reported to the Dean of Students Office.

Course Equipment

Required Text – *Essentials of Computer Architecture Second Edition*; Comer; Chapman and Hall/CRC, Copyright 2017. ISBN-13: 978-1138626591. We will cover 90+% of its content.
Copies are on reserve at MATH Library front desk. Do not try to use the First Edition of this book because it is obsolete.

Lab Kit – distributed in lab.

iClicker – for in-class quizzes.

Paper and writing implement – for in-class examples and designs.

Changes for Emergencies
In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. If an emergency occurs, you can consult the Purdue web page (http://www.purdue.edu) as well as the class web page on Blackboard for information.