CS2204 DIGITAL LOGIC & STATE MACHINE DESIGN FALL 2009

GENERAL
CS2204 LAB & ENGINEERING FUNDAMENTALS

1. Introduction

CS2204 covers theory, design analysis of digital circuits. The CS2204 lab helps students achieve the intellectual, technical and non-technical goals mentioned in the Syllabus. The lab supports lectures and introduces practical aspects of digital logic, such as current design and analysis techniques and tools as well as engineering environment fundamentals. Hence, students (i) develop a term project that reinforces concepts introduced in class and (ii) experience the digital design engineering environment and acquire the skill for it by emulating the environment where the professor, TAs and students are the project manager, senior engineers and junior engineers, respectively.

The lab emphasizes the design more than analysis by focusing on a semester-long term project. The reason is that it is harder to design than analyze. One has to practice design considerably in order to master it. The CS2204 lab helps students practice design throughout the semester ! The term project targets a **game chip**. Students design a game playing circuit that can beat human players, for example the professor ! Students' lab performance affects the term grade directly and also indirectly since each exam has questions on topics covered in the lab.

This handout presents points important for the CS2204 lab. The points are also important after this course and ***after graduation***. Specific topics covered in this handout are the lab structure and engineering environment fundamentals. Students need to bring this handout to the lab and refer to it as often as they can.

2. Digital Design Today

Today's digital design engineering environment is a fast-paced and very dynamic environment. In order to be ready for this pressure-filled work place, college students need to learn and follow some of the technical and non-technical practices of the engineering environment. The lectures and especially the lab are designed to introduce them. They are described briefly in this handout and will be discussed throughout the semester. Note that these digital circuit (digital hardware) engineering fundamentals are similar to software engineering and analog hardware engineering fundamentals and so can be used for those situations as well.

Today, digital hardware engineers develop products that are one of the three below :

- A chip
- A printed circuit board (PCB)
  - Chips cannot be used by themselves. New chips developed must be on a new PCB eventually !
- An intellectual property (IP) whose description is contained in a set of computer files.

Engineers use design goals (factors) to make decisions during the design. The goals include :

- Speed, cost, size, power consumption (allowable heat), weight, reliability, upgradibility of the chip/PCB.
  - It is not easy to satisfy the goals at the same time ! For example, increasing the speed will increase the cost and power consumption !

3. Lab Hardware and Software :

The CS2204 lab is 227RH. The lab hardware is the **Digilent** XLA5 field programmable gate array (**FPGA**) prototyping board. The FPGA chip on the board is the Xilinx SPARTAN XCS10PC84 chip. An FPGA chip is a hardware programmable chip. It emulates the circuit designed. FPGA chips are used to test the design when a **new chip** is developed. The Xilinx Spartan FPGA chip contains configurable (programmable) logic blocks (CLBs) and programmable connections. The Spartan has 196 CLBs organized as a 14x14 2-dimensional array on the chip. The Digilent URL is **http://www.digilentinc.com.** The Xilinx URL is **http://www.xilinx.com**.

The lab software is Xilinx Foundation 4.2i computer aided design (CAD) software tool. It is used to develop the game chip, i.e. to design and test it, on computers. This tool includes **schematic** and *Hardware Description Language* (HDL) design editors, logic and timing simulators and FPGA interfaces and downloaders (programmers). The CS2204 design will be schematic, not HDL. VHDL (VHSIC HDL) which is a HDL language will be discussed at the end of the semester. VHSIC stands for Very High Speed Integrated Circuit, which was a project of DARPA (Defense Advanced Research Projects Agency) in the 1980s.

- A *Xilinx project* consists of a "pdf" file and a directory of files. For example, project mux2to1 (2-to-1 MUX), has a "mux2to1.pdf" file and the directory named "mux2to1." Note that the pdf file is **not** the pdf file type used by Acroread. It is a Xilinx specific file, standing for "Project Definition File." The project directory, "mux2to1," keeps the schematic files and other project related files.

- Lab (Xilinx) projects are kept in the LABS domain with drive name "**S**" on lab PCs. To access the S drive students need to have (i) a LABS domain account and (ii) an S drive access right. Note that the S drive is accesible to the students only this semester. It is also a networked drive which means if the network is down, the S drive is not accessible. Therefore, students need to have a **USB memory stick** that keeps a copy of the S drive. Students have to copy their S drive to the USB memory after **each** lab session for continuous work this semester.

- Students need to keep their projects organized on the S drive : Projects are built on earlier projects. If not organized well, students may waste time to locate them or to redesign the same circuits from scratch. Students are suggested that on the S drive, they have a CS2204 folder. In this folder they create a folder for each experiment, for example, an "exp1" folder for Experiment 1, an "exp2" folder for Experiment 2, and so on.

- When students get in to the lab, they login to the LABS domain and start the Xilinx Foundation software whose icon is named "**Project Manager**." Students make sure they can access the S drive on the PC they are using. If a lab project is kept on the laptop, it must be so temporarily. The project must be moved to the S drive, especially before arriving to the lab : The pdf file and the directory must be moved to the S drive. Also, the USB memory has to be a duplicate of the S drive before leaving the lab.

- Students should **not** touch the FPGA board except only those parts that are **not sensitive to static electricity**, such as switches and pushbuttons. Touching the FPGA should be avoided in order not to damage it.

- When the lab is over, students need to log off and turn off both the monitor and the FPGA board.

- Students are suggested that they download necessary pages from Xilinx, Digilent, the Wakerly textbook and Texas Instruments web sites and keep them handy. Students can print certain pages that are frequently used.

4. Lab Work :

- The lab performance of students will affect the term grade : 5% of the term grade will be based on the lab. However, to earn the 5% students need to do the following :
  - Students must be present and working on the assigned topics with their teammates **well** in the lab,
    - Attending the lab session and being on time are required. Attendance is recorded in every lab session.
      - Students arriving late would have difficulty in adjusting to the lab session, delaying team's work.

- The lab performance affects the term grade **more** : Exams include the labs, i.e. circuits and concepts studied in the lab. In addition, a student working well in the lab solves problems faster during exams

- There are six (6) experiments to learn about the lab hardware and software and to complete the term project. The last experiment, Experiment 6 will be collected and comments will be made.

- Each lab session starts with taking attendance. Teammates "synchronize" with each other and the professor answers questions from the teams. Then, the professor gives a presentation to discuss important points of the lab session. Afterwards, teams continue with the lab work under TAs' supervision.

- Students must be motivated for the lab (timely arrival to the lab session, session long presence in the lab, attention to the work), concentrate on the experiments (focusing on the design), and work well with teammates. During the lab session, students are required that they not be distractive, not talk with others except with their partners only if necessary and not loudly and not go out and come back frequently.
  - Students **cannot** do email or other computer communication (i.e. chat) in the lab.
    - Students **cannot** have food and drinks in the lab.
      - Students may leave the lab to get food or a drink, provided that it is short and teammates accept it. Students must keep the project due date in mind and make sure they are on schedule to complete it. The project due date will not be postponed for a team.

- The lab will be available to students to work on experiments when a lab session is **not** scheduled. A TA will be present in the lab. The lab is supervised by Mr. Keni Yip. His office is 225RH. Note that the 775JAB PC lab also has the software installed and the term project can be worked on in that lab as well.

5. Team Work :

- Team-based design is an unquestionable necessity in digital engineering environment today. Members of a team think on a problem simultaneously, arriving at a solution faster. Although it may seem simple to do team work, it is not the case. The success of the team depends on the members' ability to *cooperate*. Hence, college students need to learn basics of team work. Team work in CS2204 targets practicing simultaneous cooperative work on a problem by a number of students to arrive at an acceptable solution fast.

- The lab projects and the homework will be done by 3- or 4-student teams. Students will choose their partners from their own lab section. In order to ensure effective cooperation, as soon as a team is formed, members of the team need to exchange their contact information : Telephone numbers, email addresses, their semester schedule, (class and work schedule), etc. to determine their weekly meeting times.

- Students will submit homework and lab projects as a team : Just one per team. This requires coordination ! So, students have to be in touch with their partners all the time. Thus, team members must carry each other's complete contact information with them all the time.

    - A student who misses a lab session will discuss with his/her lab partner(s) as to how to try to catch up. Based on partners' suggestions, the student can do the work either in the PC lab 775JAB or in the CS2204 lab when there is no lab session scheduled.

- Note that **every student has to work as if he/she has no partner**. First, the exams have lab related questions. Second, a partner might withdraw from the course and the smaller team would be doing the homework and the lab project. Finally, these should not be any concern since the homework and lab experiments are designed so that they can be done by a single student, **provided that the student has not fallen behind**.

6. Engineering Environment Fundamentals :

Today's digital engineering environment requires constant learning and adaptation. The environment is also team-based and global. Thus, engineers must (i) know how to learn fast, (ii) know how to interact with people well and (iii) have a solid technical foundation. The environment can be stressful even for experienced engineers. Thus, it is important for students to be ready for it before they graduate. The CS2204 lab is a good medium to prepare for it. It is designed to help students learn about the environment. Students need to take the advantage of this opportunity !

In today's globalized engineering environment with tight deadlines and tight budgets, managers/employers want their engineers to have the following two properties :

- Problem solving skills ! Even on a global scale ! When there is a problem to be solved, they want to hear from you "No problem ! I can solve it !" They do **not** want to hear "I don't know about it ! I never learned it ! I cannot do it !"

- Being systems oriented ! Even on a global scale ! They want you to know not only the part (block) of the system you work on, but also the other parts. So, you know how the whole system (black box) works and how the pieces relate to each other. They do **not** want to hear "My job is only this part (block) ! I don't know about the rest !"

These two properties become more important when there is an economic recession that causes staff reductions. The remaining staff has to do more work as there are less people at the company !

On the non-technical side, students need to realize that the following are important points for engineers :

- Technical performance and skills are **not** everything.

- One should **not** take anything that is **not** earned : Someone else's intellectual property (IP).

    - But, it does not mean one has to be on a one-person crusade. First, we are not machines. Second, we all need each other.

- Help others (colleagues) before asking for help.

    - No one can survive alone. One should not ignore people around.

- Find the balance !

Non-technical skill means : One knows what to do how, where and when in the work place. For senior engineers it also means to be able to speak well and to be patient, a good listener, inspirational, motivational, and firm but fair.

- A **smile** can unlock many doors !

CS2204 is designed to help students be system oriented problem solvers. It is also designed to help students understand the above engineering environment dynamics : Both technical and **non-technical**, the latter of which is sometimes more important than the first. The professor expects students treat the course as a cultivating ground of preparation for engineering life : The lab is the place engineering environment basics are learned and improved upon :

- Team-oriented labs and homework,
- Rules and conventions in the lab and classroom to bolster technical and non-technical skills and
- The professor and TAs are the project manager and senior engineers, supervising students who are junior engineers.

The professor will convey messages to remind students about the engineering environment by giving analogies from the college environment and ask from students to train for the engineering life by practicing college analogies :

- In college, students should not do things that they would not do as engineers. Such as :
  - Arguing with the project manager ?
  - Arguing with team members ?
  - Arriving late at a team meeting ?
  - Delaying the completion of the project part (block) assigned ?

7. Digital Design Trends

Today's digital circuits are very complex, requiring specific techniques and tools. The techniques include :

- **Top-down** design :
  - Block-based, layered, structured design : Simple concepts, blocks and subblocks, are dealt with first, not circuits. Therefore, one starts with the input/output relationship of a block, partitions it into subblocks and continues this process until each (sub)block is simple enough to be implemented by circuits quickly.
  - CS2204 top-down design : the term project is a black box in the beginning with a specific input/output relationship (operation). It will then be partitioned into six blocks each of which will be partitioned into subblocks, subsubblocks, and so on.
- **Team-based** design :
  - Digital hardware is designed in parallel by team members to complete the product in time for mass production : Time-To-Market (**TTM**). The number of team members depends on the complexity of the design.
  - CS2204 teams : 3- or 4-student teams complete the project by the last lab session of the semester !
- **Core-based** design :
  - Most difficult blocks (IP) are licensed from other companies to save time.
  - CS2204 core-based design : Students will be given five blocks. They will design the remaining one block.

Even if the above techniques are utilized (top-down, team-based and core-based design), today's circuits are still too complicated. Thus, one needs powerful tools and devices to further simplify the task of digital design :

- **Computer aided design** (CAD) software tools are used to develop digital circuits on computers. The CAD software abstracts (hides) the details unnecessary at the moment and so speeds up the development phase.
  - CS2204 CAD software : Xilinx Foundation 4.2i software.
- **Field programmable gate array** (FPGA) prototyping boards are used to test the new chip design physically. FPGAs emulate the new chip, allowing the designers to catch additional errors, not caught during simulations on CAD software..
  - The CS2204 FPGA board : Digilent XLA5 FPGA board to test the game chip design.
    - CS2204 FPGA : Xilinx SPARTAN XCS10PC84.
- There is a web site that has been set up to help Xilinx university users : **http://www.xilinx.com/univ**.