# CS 251: Computer Architecture and Assembly Language

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| **Term**: | Spring 2023 |
| **Credits**: | 3 |
| **Lectures**: | 9:10 AM – 10:10 AM, MW in HS 208 |
| **Lab**: | 9:10 AM – 10:10 AM, F in HS 101A |
| **Prerequisites**: | CS 221 with a C or better. |

## Instructor


| | |
|---|---|
| **Instructor**: | Scott Summers |
| **Email**: | `summerss@uwosh.edu` |
| **Phone**: | 920-424-1324 |
| **Office**: | Halsey 220 |

| **Office hours**: | Indicated by the cells shaded in GRAY in the following table and subject to change. The BLACK cells are times at which I'm not available because I'm either teaching, doing research, in a meeting, or eating lunch. |

| | Mon | Tues | Wed | Thu | Fri |
|---|---|---|---|---|---|
| 8:30 AM | | | | | |
| 9:00 | | | | | |
| 9:30 | | | | | |
| 10:00 | | | | | |
| 10:30 | | | | | |
| 11:00 | | | | | |
| 11:30 | | | | | |
| 12:00 PM | | | | | |
| 12:30 | | | | | |
| 1:00 | | | | | |
| 1:30 | | | | | |
| 2:00 | | | | | |
| 2:30 | | | | | |
| 3:00 | | | | | |

As indicated above, I hold five total scheduled office hours per week. You don't need to schedule an appointment with me if you want to stop by during my scheduled office hours. If you want to meet virtually, via Microsoft Teams, then send me an email a few minutes before you'd like to meet, simply asking if I'm available to meet virtually. I'll respond as soon as I'm available. If you'd like to meet with me outside of my scheduled office hours, then please email me and we'll work out a time that works for both of us. If my office hours ever change, even for a single day, then I'll send the class updates via the course webpage.

## Course description

This course aims to give students an overview of processor and memory hardware, and to teach them how high-level language programs map onto some Reduced Instruction Set Architecture or RISC computer.

Students will learn how computer hardware supports the instruction set architecture. Students will be able to analyze why programs behave the way they do and how inefficiencies arise. Students will learn how to implement pointers and references in machine language.

## Learning outcomes

At conclusion of the course, students will be able to:

1. Express characters and integers in binary, hexadecimal, signed and unsigned representations.
2. Determine whether overflows occur in signed or unsigned additions and subtractions of integers.
3. Write normalized and denormalized floating point numbers in single and double precision using the IEEE 754 Floating Point Standard.
4. Analyze the IEEE 754 Floating Point Standard and determine what integers cannot be represented exactly by the Floating Point Standard.
5. Organize the memory layout of global integers and characters assuming the Little-Endian and Big-Endian notations.
6. Edit an assembly language program, assemble the program and print output on console using Linux.
7. Design assembly language program given high-level source code.
8. Implement assembly language programs that read in integers from console, process the input and print results on the console.
9. Implement high-level language control structures in assembly language.
10. Implement one and two-dimensional arrays and control structures in assembly language (do-while, if-else, and for loop).
11. Write nested function calls using stack frames and local variables.
12. Write an assembly language program to call recursive functions.
13. Implement C/C++ pointers and references.
14. Implement pass-by-value and pass-by-reference parameter passing.
15. Describe a buffer overflow and why it is a potential security problem.

## Course website

The course website is: `https://uwosh.edu/canvas/`. You should check Canvas on a regular basis, perhaps two or three times per day.

## Required Textbook

We will be using an online "zyBook" textbook. Follow these instructions:

1. Sign in or create an account at `http://learn.zybooks.com/`.
2. Enter zyBook code **UWOSHCOMPSCI251SummersSpring2023**.
3. Subscribe.

A subscription is **$58**. You may begin subscribing on January 16, 2023. Subscriptions will last until May 26, 2023.

## Course grade

Your final course grade will be based on the following types of assessment items.

**5% QUIZZES**

You will be given one quiz roughly every week. Quizzes will be taken at the end of class. Each quiz is equally-weighted. Calculators will not be allowed for any of the quizzes. Each quiz will test your knowledge of the material from roughly the prior week but older material may be covered depending on how the class performs on the prior quiz.

**10% ZYBOOK ACTIVITIES**

Throughout the semester, you will have to complete activities selected from the course zyBook. Before each lecture, except on exam days, a zyBook activity may be assigned. Each zyBook activity will be comprised of participation questions relating to the new material and challenge questions relating to previous material. The idea is that you must do the zyBook activity for the next lecture before coming to lecture. That way, you'll already have an idea of what's going on during that lecture. The challenge activities will test your knowledge of concepts previously covered.

**25% LABS**

There will be weekly labs on Friday in HS 101A. Attendance is strongly encouraged. Associated with each lab will be a lab assignment due before the start of the following lab. Each lab assignment is equally-weighted.

**60% EXAMS**

There will be three, equally-weighted, in-class exams. Calculators will not be allowed for any of the exams but you may use a note sheet. Your note sheet must be 8.5" by 11", hand-written and can utilize both sides of the paper. Note sheets must be turned in with your exam, otherwise you may not receive full credit for your exam. Exam material will come from the lecture notes, assignments and zyBook activities. There will be more information about each exam as it approaches.

## Grading scale

Grading will be on a plus/minus system. Grading may be done on a curve depending on the overall performance of the class. If no curve is used, then your grade will be computed based on the following:

| Percentage | Grade |
|---|---|
| $> 91$ | A |
| $> 89$ and $\leq 91$ | A- |
| $> 87$ and $\leq 89$ | B+ |
| $> 81$ and $\leq 87$ | B |
| $> 79$ and $\leq 81$ | B- |
| $> 77$ and $\leq 79$ | C+ |
| $> 71$ and $\leq 77$ | C |
| $> 69$ and $\leq 71$ | C- |
| $> 67$ and $\leq 69$ | D+ |
| $> 61$ and $\leq 67$ | D |
| $> 55$ and $\leq 61$ | D- |
| $\leq 55$ | F |

## Re-grading

If you believe an assessment item (e.g., exam, etc.) was graded incorrectly or unfairly and would like to have it re-graded, please let me know about it in writing within one day of receiving the assessment item back. I will re-grade the entire assessment item and you may gain or lose points accordingly.

## Late work

If you are unable to take a scheduled exam at its normal time, then ,it may be possible to take a make-up exam provided that you do both of the following, which are then subject to my approval:

1. Make arrangements prior to the scheduled exam (for last minute emergencies, call me at 920-424-1324 or leave a message at the Computer Science office, 920-424-2068. **No after-the-fact notifications will be accepted**.

2. Have a written medical excuse signed by the attending physician OR have a note of justification from the Dean of Students Office.

In some cases, only one make-up exam will be given. It will be a comprehensive exam given at an arranged time during the last week of the semester.

Late work will NOT be accepted. Late work is worth 0 points. Extensions may be granted at the discretion of the instructor if you provide a valid justification.

In general, the following are the only valid excuses for not completing or submitting an assessment item on time:

- Medical illness – provide to me an official note from a medical provider (or the Dean of Students) supporting your claim of a medical illness and describing its severity.

- Family death – provide to me the name of the deceased, the name of the funeral home, and your parent's address, to which I can send my condolences.

- Religious holiday – provide to me before the third week of the semester a list of all the dates of conflict.

- University-sanctioned events, e.g., athletic competition, student organization event, conference attendance, career fair, etc. – provide to me before the third week of the semester a list of all the dates of conflict, along with corresponding supporting documentation on official university letter head.

Work is not a valid excuse to miss class. Your job must work around school, and not the other way around.

If you have four or more unexcused absences, then I reserve the right to automatically fail you.

If you have six or more medical absences, then you must medically withdraw from the course.

## University policy on academic integrity

The University of Wisconsin Oshkosh is committed to a standard of academic integrity for all students. The system guidelines state:"Students are responsible for the honest completion and representation of their work, for the appropriate citation of source, and for respect of others' academic endeavors" (UWS 14.01, Wisconsin Administrative Code).

Often, students are not aware of the ways to identify and avoid plagiarism. Therefore, it is important to educate yourself about how to give proper credit to sources that you use in your assignments. For writing assignments, you can consult the Purdue Owl website on how to identify and avoid plagiarism: `https://owl.english.purdue.edu/owl/resource/589/02/` and `https://owl.english.purdue.edu/owl/resource/589/03/`. This website outlines the strategies for avoiding plagiarism in this course. However, other courses may demand knowing other ways to identify and avoid plagiarism. Therefore, I encourage you to consult with me if it is unclear to you how you give proper credit to your sources of information.

According to the Dean of Students
(see `https://uwosh.edu/deanofstudents/student-conduct/academic-misconduct/`), examples of academic misconduct include, but are not limited to:

- plagiarism (turning in work of another person and not giving them credit),

- stealing an exam or course materials,
- copying another student's homework, paper, or exam,
- cheating on an exam (copying from another student, turning in an exam for re-grading after making changes, working on an exam after the designated time allowance),
- providing solutions on online forums (e.g., Discord, etc.), and
- falsifying academic documents.

In sum, all material turned in for this course must be original. In this course, you may not re-use papers or projects from other sections of this course, from other courses you have completed, or other courses you are currently completing. This class is a specific event in your learning process. To learn, you must engage in the material and complete the work. Thus, work from other experiences is not acceptable. All work turned in that is plagiarized will receive a "0" in the course.

## Accommodations

UW Oshkosh supports the right of all enrolled students to a full and equal educational opportunity. It is the University's policy to provide reasonable accommodations to students who have documented disabilities that may affect their ability to participate in course activities or to meet course requirements.

Students are expected to inform instructors of the need for accommodations as soon as possible by presenting an Accommodation Plan from either the Accessibility Center, Project Success, or both. Reasonable accommodations for students with disabilities is a shared instructor and student responsibility.

The Accessibility Center is part of the Dean of Students Office and is located in 125 Dempsey Hall. For more information, email `accessibilitycenter@uwosh.edu`, call 920-424-3100, or visit the Accessibility Center's website at `https://uwosh.edu/deanofstudents/accessibility-center/`.

## Statement regarding diversity, equity & inclusion

Diversity drives innovation, creativity, and progress. At the University of Wisconsin Oshkosh, the culture, identities, life experiences, unique abilities, and talents of every individual contribute to the foundation of our success. Creating and maintaining an inclusive and equitable environment is of paramount importance to us. This pursuit prepares all of us to be global citizens who will contribute to the betterment of the world. We are committed to a university culture that provides everyone with the opportunity to thrive.

## Required disclosure statement

Students are advised to see the following URL for disclosures about essential consumer protection items required by the Students Right to Know Act of 1990:
`https://uwosh.edu/financialaid/consumer-information/`

## Tentative daily schedule

Starting on the next page, a tentative daily schedule is given (subject to change):

| Day | Date | Action items and topics to be covered |
|---|---|---|
| 1 | Monday, Jan 30 | Take attendance<br>Review syllabus, course logistics, etc.<br>Bits, bytes, character data representation (1.1) |
| 2 | Wednesday, Feb 1 | Positional number systems, binary number system,<br>decimal to binary conversion,<br>binary addition algorithm (1.2) |
| 3 | Friday, Feb 3 | Lab 1<br>Introduction to basic Linux shell commands<br>Introduction to C: variables, operators, `printf` |
| 4 | Monday, Feb 6 | Binary, hexadecimal, and octal number systems (1.4)<br>Quiz 1 - covers content from days 1 through 3 |
| 5 | Wednesday, Feb 8 | Binary encoding of negative numbers,<br>sign-magnitude representation<br>two's complement representation (1.3) |
| | Thursday, Feb 9 | Lab 1 DUE at 8:00 AM |
| 6 | Friday, Feb 10 | Lab 2<br>Continued practice with basic Linux shell commands<br>Introduction to C: branches and loops |
| 7 | Monday, Feb 13 | Addition in two's complement representation,<br>overflow in unsigned arithmetic,<br>overflow in two's complement arithmetic (1.3)<br>Quiz 2 - covers content from days 4 through 6 |
| 8 | Wednesday, Feb 15 | Introduction to C: formatted output, signed and unsigned<br>integers, `sizeof`, unreported overflow |
| | Thursday, Feb 16 | Lab 2 DUE at 8:00 AM |
| 9 | Friday, Feb 17 | Lab 3<br>Continued practice with basic Linux shell commands<br>Introduction to C: arrays |
| 10 | Monday, Feb 20 | Bitwise logical operators in C<br>Shift operators in C and Java<br>Sign extension operation<br>Quiz 3 - covers content from days 7 through 9 |
| 11 | Wednesday, Feb 22 | Floating-point numbers and normalized scientific notation,<br>fractions in binary, loss of precision (1.6) |
| | Thursday, Feb 23 | Lab 3 DUE at 8:00 AM |
| 12 | Friday, Feb 24 | Lab 4<br>Continued practice with basic Linux shell commands<br>Introduction to C: strings, user-defined functions,<br>dynamic memory management |
| 13 | Monday, Feb 27 | IEEE 754 floating-point standard (1.6)<br>Quiz 4 - covers content from days 10 through 12 |
| 14 | Wednesday, Mar 1 | Decimal to binary floating point (1.6)<br>IEEE 754 denormalized and other special values |
| | Thursday, Mar 2 | Lab 4 DUE at 8:00 AM |
| 15 | Friday, Mar 3 | Review for Exam 1 |
| 16 | Monday, Mar 6 | Exam 1 - covers activities and content from days 1 through 15 |

The tentative daily schedule is continued on the next page...

Continuation of tentative daily schedule:

| Day | Date | Action items and topics to be covered |
|---|---|---|
| 17 | Wednesday, Mar 8 | Programmable processor architecture, introduction to MIPS (2.1)<br>Addressability, address space, alignment, Endianness (2.3) |
| 18 | Friday, Mar 10 | Lab 5<br>Continued practice with basic Linux shell commands<br>Introduction to C: pointer arithmetic, and<br>dynamic memory management |
| 19 | Monday, Mar 13 | Data transfer instructions `lw` and `sw` (2.2),<br>Arithmetic instructions `add` and `addi` (2.4)<br>Quiz 5 - covers content from days 17 through 18 |
| 20 | Wednesday, Mar 15 | Use of MIPS registers with basic arithmetic operators (2.6)<br>`sub` and `mul` instructions (2.7)<br>Register conservation (4.3) |
| | Thursday, Mar 16 | Lab 5 DUE at 8:00 AM |
| 21 | Friday, Mar 17 | Lab 6<br>Introduction to MARS<br>Pseudo-instructions<br>`syscall`s |
| | Monday, Mar 20<br>Wednesday, Mar 22<br>Friday, Mar 24 | SPRING BREAK<br>SPRING BREAK<br>SPRING BREAK |
| 22 | Monday, Mar 27 | `bne`, `beq`, and `j` instructions (2.8)<br>`slt` instruction (2.9)<br>Quiz 6 - covers content from days 19 through 21 |
| 23 | Wednesday, Mar 29 | Software development cycle<br>Implementing variable declaration (4.1)<br>Implementing expressions using left-to-right evaluation (4.2) |
| | Thursday, Mar 30 | Lab 6 DUE at 8:00 AM |
| 24 | Friday, Mar 31 | Lab 7<br>Practice with: `li`, `la`, `move`, `add`, `sub`, `j`, `syscall`, `blt`, `bge`, `bne` |
| 25 | Monday, Apr 3 | Implementing `if-else` without expressions (4.4)<br>Quiz 7 - covers content from days 22 through 24 |
| 26 | Wednesday, Apr 5 | Implementing `if-else` with expressions (4.5)<br>Implementing `while` loops (4.6) |
| | Thursday, Apr 6 | Lab 7 DUE at 8:00 AM |
| 27 | Friday, Apr 7 | Lab 8<br>Security topic: buffer overflow demo (attendance is required) |
| 28 | Monday, Apr 10 | Implementing `for` loops (4.6)<br>Quiz 8 - covers content from days 25 through 27 |
| 29 | Wednesday, Apr 12 | Load and stores with offsets (3.3)<br>Implementing pointers and 1D arrays in assembly language (4.8) |
| 30 | Friday, Apr 14 | Review for Exam 2 |
| 31 | Monday, Apr 17 | Exam 2 - covers activities and content from days 17 through 30 |

The tentative daily schedule is continued on the next page...

Continuation of tentative daily schedule:

| **Day** | **Date** | **Action items and topics to be covered** |
|---|---|---|
| 32 | Wednesday, Apr 19 | 2D arrays |
| 33 | Friday, Apr 21 | Lab 9<br>Selection, short-circuiting, iteration, and 1D arrays |
| 34 | Monday, Apr 24 | Function calls<br>System stack<br>Calling functions with instructions `jal` and `jr` (3.1)<br>Leaf and non-leaf functions<br>Quiz 9 - covers content from days 32 through 33 |
| 35 | Wednesday, Apr 26 | Function calls: parameters and return values,<br>reference and array parameters (3.4) |
| | Thursday, Apr 27 | Lab 9 DUE at 8:00 AM |
| 36 | Friday, Apr 28 | Lab 10<br>Iteration, pointers, 2D arrays, selection, short-circuit evaluation |
| 37 | Monday, May 1 | Functions that use registers (4.7),<br>MIPS register conventions<br>Activation records<br>Quiz 10 - covers content from Days 34 through 36 |
| 38 | Wednesday, May 3 | MIPS register conventions<br>Implementing functions with local variables |
| | Thursday, May 4 | Lab 10 DUE at 8:00 AM |
| 39 | Friday, May 5 | Lab 11<br>Converting a C program with functions to assembly |
| 40 | Monday, May 8 | Wrap-up<br>Quiz 11 - covers content from Days 37 through 39 |
| 41 | Wednesday, May 10 | Review for Exam 3 |
| | Thursday, May 11 | Lab 11 DUE at 8:00 AM |
| 42 | Friday, May 12 | Exam 3 – taken in HS 101A – covers activities and content from<br>days 32 through 41 |