Systems Foundations

CS 631 (4 units)
Spring 2026
TR 8:00am - 9:45am 01/26/26 - 05/14/26 LS 307
TR 2:40pm - 4:25pm 01/26/26 - 05/14/26 LS 307

Lecture

Instructor Information

Gregory Benson (Instructor)
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Office Hours
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Course Description

Study of the foundations of computer systems and the hardware/software interface. Topics span the design, implementation, and programming of processor architectures, networks, and operating systems. Computer architecture topics include instruction set design, cache design, hardware virtual memory, and virtualization. Network topics include network interfaces, protocol design, and network programming. Operating system topics include kernel design, the system call interface, resource management, software virtual memory, and file systems. Programming projects required. Four hour lecture.

In this course we will study the foundations of computer systems and the hardware/software interface. The overall goal of this course is provide you with a solid foundation in how computer systems work at a low level. Even if you program primarily in high-level languages such as Java, JavaScript, and Python, it is important to understand how software interacts with computer processors, how languages are implemented, and how an OS kernel provides essential support to run programs. You will learn about language processing and compilers, assembly language programming, machine code, machine emulation, digital design, processor design, and OS kernel design. The course will consist of readings, lectures, and projects from each of the topic areas. Programming will be done in both the C programming language, the Rust programming language, and RISC-V assembly. Digital design will be done using the Digital schematic design tool and HDL. You will also gain experience in working with UNIX/Linux development tools and working from the command line. Finally, using coding agents such as Claude Code will be required.

Course Learning Outcomes

Upon completion of this course the students will have learned the following topics:

1. Work effectively at the UNIX command line / shell (All Projects)
2. Implement a scanner, parser, and interpreter for a simple language in C and Rust (Project01)
3. Construct and deconstruct binary-level data representations for integers, floats, strings, and machine instructions (Project01, Project03)
4. Translate C code snippets into RISC-V assembly language by hand (Project02)
5. Implement a RISC-V code generator for a simple language in C and Rust (Project02)
6. Implement an RISC-V processor emulator in C and Rust (Project03)
7. Understand and evaluate cache design and behavior (Project03)
8. Compose digital circuits into architectural components (Project04 and Project05)
9. Design and implement a working processor for a subset of the RISC-V instruction set (Project05)
10. Pipeline processor design and hazard mitigation (Project06)
11. Write programs using UNIX system calls and modify/add system calls in the kernel (Project07)
12. Understand OS kernel structure, process isolation, and virtual memory (Project08)

Assignments

In this class there will be two types of student work: labs and projects.

Labs consist of programming problems to help you learn the concepts discussed in class and prepare you for the upcoming projects. In some cases the code you write in the labs will be used in the projects. Your score for the labs will generally be determined by automated tests. Note that labs must be turned by the stated due date and time. Late labs will not be accepted. Submit what you have working to your GitHub lab repo before the due date and time.

Projects are one of the main assessment tools for the course and correspond to each learning outcome shown in parenthesis above. Projects will be graded for correctness (using the Autograder) and repo/code quality. If you do not finish a project by the due date and time, turn in what you have completed for partial credit. You will be allowed 1 week after scores have been submitted to Canvas to earn up to 75% back on any points missed. After 1 week you can earn up to 50% back until the end of the semester (the last Final day). You can earn back 100% of any points missed for repo/code quality.

Grading Breakdown and Grading Policies

Assignments

1. Labs 10%
2. Project01 - The NTLang Interpreter: 10%
3. Project02 - RISC-V Assembly and NTLang Code Generation: 10%
4. Project03 - RISC-V Emulator and Cache Simulator: 15%
5. Project04 - Digital Design 5%
6. Project05 - Single Cycle Processor: 15%
7. Project06 - Pipelined Processor Hazard Unit: 10%
8. Project07 - System Calls %10
9. Project08 - Processes and Virtual Memory %15

Policies

1. Attendance is not required by highly encouraged. You can attend via Zoom and the lectures will be recorded.
2. Neatness counts, for both source code and circuit schematics
3. Original Work
    1. You may get explanatory help from the instructor, TAs, friends, tutors, Internet sites, and generative AI

    2. You can use generative AI and coding agent, but ou must turn in work that you personally explain.
    3. You must not provide your original work to other students (giving your solutions can result in a 0)
    4. No credit will be given for work which violates this policy
    5. Repeated violations will result in a F in the course and will be reported to the CS Department Chair and the USF Academic Integrity Committee
4. Deadlines
    1. Lab must be turned in on time for credit.
    2. If you are not done with a project by the deadline, you should turn in what you have working to get full credit for that work
    3. Late work and corrections may be turned in for up to 75% credit, up to one week after the due date, then 50% until the end of the semester (the last day of finals).
    4. Extensions for full credit are not given except in extenuating circumstances, which you must discuss with the instructor in advance
5. Letter Grades are assigned according to the following table, without rounding or curving:

    93.33% - 100%: A
    90.00% - 93.32%: A-
    86.67% - 89.99%: B+
    83.33% - 86.66%: B
    80.00% - 83.32%: B-
    76.67% - 79.99%: C+
    73.33% - 76.66%: C
    70.00% - 73.32%: C-
    66.67% - 69.99%: D+
    63.33% - 66.66%: D
    60.00% - 63.32%: D-
    Below 60%: F

Texts and Supplies

Claude Code Access

Notes: The Pro subscription for $20/month should be fine.

Where to purchase (URL): https://code.claude.com/docs/en/overview

The C Programming Language
ISBN: ISBN-10 ： 0131103628
Authors: Brian W. Kernighan and Dennis M. Ritchie
Publisher: Pearson
Edition: March 22, 1988
Where to purchase (URL): https://www.amazon.com/Programming-Language-2nd-Brian-Kernighan/dp/0131103628?crid=3BML4RVG5428P&keywords=the+c+programming+language&qid=1706835688&sprefix=the+c+programming+langaug,aps,128&sr=8-1
Required or recommended?: Optional

Digital Design and Computer Architecture, RISC-V Edition
ISBN: ISBN-10 ： 0128200642
Authors: Sarah Harris and David Harris
Publisher: Morgan Kaufman
Publication Date: October 22, 2021
Edition: 1st
Where to purchase (URL): https://www.amazon.com/Digital-Design-Computer-Architecture-RISC-V/dp/0128200642?crid=34WRUY9JU01YE&keywords=Digital+design+and+computer+architecture+riscv&qid=1706835841&sprefix=digital+design+and+computer+architecture+riscv,aps,126&sr=8-1
Required or recommended?: Optional

Course Schedule

Day	Date	Event	Activities
Tuesday	**1/23/2024**		
Thursday	**1/25/2024**		
Tuesday	**1/30/2024**		
Thursday	**2/1/2024**		
Tuesday	**2/6/2024**		
Thursday	**2/8/2024**		
Tuesday	**2/13/2024**		
Thursday	**2/15/2024**		
Tuesday	**2/20/2024**		

Thursday	**2/22/2024**		
Tuesday	**2/27/2024**		
Thursday	**2/29/2024**		
Tuesday	**3/5/2024**		
Thursday	**3/7/2024**		
Tuesday	**3/12/2024**	Spring Break (No Class)	
Thursday	**3/14/2024**	Spring Break (No Class)	
Tuesday	**3/19/2024**		
Thursday	**3/21/2024**		
Tuesday	**3/26/2024**		
Thursday	**3/28/2024**	Easter Holiday begins at 4:00 P.M.	
Tuesday	**4/2/2024**		
Thursday	**4/4/2024**		
Tuesday	**4/9/2024**		
Thursday	**4/11/2024**		
Tuesday	**4/16/2024**		
Thursday	**4/18/2024**		
Tuesday	**4/23/2024**		
Thursday	**4/25/2024**		
Tuesday	**4/30/2024**		
Thursday	**5/2/2024**		
Tuesday	**5/7/2024**		
Thursday	**5/9/2024**	Last Day of Classes	

Program Learning Outcomes

Theory: explain and analyze standard computer science algorithms and describe and analyze theoretical aspects of various programming languages

Application: apply problem-solving skills to implement medium- and large- scale programs in a variety of programming languages

Systems: describe the interactions between low-level hardware, operating systems, and applications

Project: demonstrate effective communication and organization as part of a team of software developers or researchers collaborating on a large computer program

University Policies

Credit-hour Policy

One unit of credit in lecture, seminar, and discussion work approximates one hour of direct faculty instruction (or 50 minutes plus a break) and a minimum of two hours of out-of-class student work per week through one 15-week semester. For further details, see USF's Credit Hour Policy.

The below resources and additional information can be found in the Student Life Resource Toolkit.

Students with Disabilities

The University of San Francisco is committed to providing equal access to students with disabilities. If you are a student with a disability, or if you think you may have a disability, please contact Student Disability Services (SDS) at sds@usfca.edu or (415) 422-2613, to speak with a disability specialist (please note all communication with SDS is private and confidential).
If you are eligible for accommodations, please request that your accommodation letter be sent to me as soon as possible (students are encouraged to contact SDS at the beginning of the semester), as accommodations are not retroactive. Once I have been notified by SDS of your accommodations we can discuss your accommodations and ensure your access to this class or clinical setting. For more information please visit the SDS website.

Behavioral Expectations

The University of San Francisco is committed to providing an environment consistent with the academic nature and core values of the institution in which students can participate in learning as a humanizing, social activity rather than a competitive exercise to support the full, integral development of each person and all persons, with the belief that no individual or group may rightfully prosper at the expense of others.

It is important you know what is expected of you academically and behaviorally through the published course syllabus, the Student Conduct Code, and other instructions provided by the instructor. Therefore, you are expected to uphold the following:

- Behave in accordance with the Student Conduct Code and other USF policies
- Refrain from disrupting the ability of fellow students to learn or the instructor's ability to teach. Examples of disruption include:
    - Cell phone or computer use that significantly or repeatedly distracts others
    - Coming to class late, leaving early, or excessively physically relocating oneself in the classroom
    - Speaking frequently without being called on
    - Yelling, cursing, or engaging in aggressive behavior
- When interacting online, communicate in a respectful fashion. This includes, but is not limited to:
    - Refraining from name calling, profanity, or typing in all capital letters
    - Sending multiple emails with one sentence
    - Avoiding rants or discussing non-relevant topics

Open discussion and disagreement are encouraged when done respectfully and in the spirit of academic discourse. There are also a variety of behaviors that, while not against a specific University policy, may create disruption in this course. Students whose behavior is disruptive or who fail to comply with the instructor may be dismissed from the class for the remainder of the class period and may need to meet with the instructor or Dean prior to returning to the next class period. If necessary, referrals may also be made to the Student Conduct process for violations of the Student Conduct Code.

Academic Integrity

As a Jesuit institution committed to cura personalis—the care and education of the whole person — USF has an obligation to embody and foster the values of honesty and integrity. All members of the USF academic community are responsible for maintaining the standards of honesty and integrity. The honor code applies to all students (undergraduate and graduate) in the College of Arts and Sciences, the School of Education, the School of Management, and the School of Nursing and Health Professions. Faculty and students in

the School of Law should review their own honor code for policies and procedures. Students enrolled in distance learning (online courses) are subject to these policies as well as supplemental policies set forth by their program. All students should review and familiarize themselves with the honor code, prohibited conduct, and procedures.

Counseling and Psychological Services

Many college students experience mental health difficulties. Counseling and Psychological Services (CAPS) is a great source of support for addressing a range of mental health needs, including anxiety, stress, loneliness, relationship struggles, grief/loss, adjusting to change, identity development, racial/cultural concerns, and mild to moderate depression.

CAPS offers in-person and remote individual and group therapy to enrolled students. Students seeking services are scheduled for a 15-20-minute phone screening to assess immediate risk, as well as identify initial treatment needs, and make recommendations for next steps. These may include a crisis or risk assessment, brief individual therapy (every 2-3 weeks), single session therapy, weekly group therapy, or referrals to off-campus providers. Please note, CAPS does not have a psychiatrist on staff to prescribe medication. Students in need of medication or with more complex mental health concerns are referred off-campus for specialized, comprehensive, treatment and/or ongoing, longer-term therapy. To make an appointment, call CAPS at 415.422.6352 or request an appointment via the CAPS website. CAPS does not accept walk-in appointments.

Students with urgent mental health needs can call the **CAPS All-Hours line (855-531-0761)** to immediately speak with a mental health clinician. The CAPS All Hours line is **available 24/7**, including weekends/holidays, and accepts international calls, and should only be accessed for mental health crises. For all other mental health concerns, including scheduling, canceling, rescheduling, or leaving a message for a CAPS clinician, please call CAPS at 415.422.6352 during normal business hours.

All students are encouraged to check out the CAPS website and access our extensive online resources, podcasts, mental health apps, videos, self-care strategies, and more.

If you are concerned about a student and would like someone to follow up, please contact the Dean of Students Office at 415.422.5330. If you know someone who is an immediate

risk of harming themselves or others, please contact Public Safety at 415.422.2911 in San Francisco, out of state or additional locations within California dial 911, or call the National Suicide & Crisis Lifeline by dialing 988.

Title IX

The Title IX Office seeks to stop, remedy, and prevent occurrences of sex and gender-based discrimination, sexual harassment, and sexual violence. The University has a Policy on Nondiscrimination Based on Sex and Gender, Sexual Harassment, and Sexual Misconduct for all Students, Employees, and Third-Parties. If you have experienced any behaviors related to this policy, we encourage you to report the incident. If you report these behaviors to any staff or faculty member, they must notify the USF Title IX Coordinator.

Students who wish to report any sexual misconduct should use the online mandatory reporting form. You can also contact the Title IX Office directly by calling (415)422-4563, emailing titleix@usfca.edu, or visiting our office in Lone Mountain, Room 145.

As an employee at USF, and your Professor, I am a mandatory reporter, meaning I have to share any instances of sexual harassment or sexual violence shared with me or that become known to me. I will have to share this information, including names and any details known, to the Title IX Office to connect you with resources. If you would like more information about the resources available, you can ask me at any time this semester. You do not need to tell me why you are asking to get help for a friend, another student, or yourself.

If you are interested in accessing confidential resources, please consider these options. If you report any information to the following, it will not generate a report to the Title IX office:

- Students may speak to someone confidentially by contacting Counseling and Psychological Services at (415) 422-6352, or speaking to a clergy member in University Ministry at (415) 422-4463.
- To find more about reporting sexual misconduct (including sexual assault, relationship violence, or stalking) and resources at USF, visit the USF Title IX website.

- For off-campus resources, contact San Francisco Women Against Rape (SFWAR) at (415) 647-7273; www.sfwar.org

If during the course of the semester you need accommodations related to pregnancy or parenting, please let me know and I can connect you to the Title IX office. They are able to offer support through arranging accommodations, leave, or other support. The Title IX office is responsible for ensuring pregnant and postpartum students get the changes they need to stay healthy while being able to continue their education.

Confidential Resources for Reporting Sexual Misconduct

- Students may speak to someone confidentially which will not generate a report to the Title IX Office by contacting Counseling and Psychological Services at (415) 422-6352 during M-F 9-4pm, or speaking to a clergy member in University Ministry at (415) 422-4463.
- If you need to speak to a mental health clinician immediately, please call the **CAPS 24/7 All Hours Line at 855-531-0761** (available daily, including weekends and holidays, and accepts international calls), Public Safety (415-422-2911), 911, the Suicide Hotline (dial 988), or go to your nearest emergency room
- For off-campus resources and local Bay Area organizations check here.

Learning, Writing, and Speaking Centers

The Learning, Writing, and Speaking Centers (LWSC) at USF provide individualized support to assist students in better understanding course material and to aid them on their path to success. Services are free and include tutoring, collaborative peer support services, academic skills coaching, writing, and speaking support. Services are available in-person and on Zoom.

LWSC staff can be reached Monday through Thursday between 9:00am-8:00pm and Friday between 9:00am-5:00pm at LWSC@usfca.edu or through the chatbox on our myUSF webpages or by phone at (415) 422-6713. To make an appointment for subject tutoring, academic skills coaching, the writing center, or the speaking center, students should visit the Student Appointment Dashboard.

Communication

All course communications, like all other USF communications, will be sent to your USF official email address. You are therefore strongly encouraged to monitor that email account.

Gleeson Library

Looking for help with a research paper or project? Set up a consultation with a Librarian or get 24/7 research help online.

Attendance Policy

Attendance is strongly recommended but is not required.

Additional USF Resources

USF Food Pantry

The USF Food Pantry is an intermediate, short-term solution for any registered USF student to receive food and toiletry resources. Students are invited to stop by the pantry located on the first floor of Gleeson Library in the Atrium, and take the items that they need. Items are available on a first-come, first-serve basis until our supply is depleted. You will be asked to check-in via QR code before entering the pantry. For more information and the current schedule, visit the USF food pantry website. If you have further questions, please contact the Pantry Coordinator at usfpantry@usfca.edu or 415-422-4099 (during business hours Monday thru Friday from 9:00am - 5:00pm). You can find out about additional food security resources through the USF food insecurity resource page and the CalFresh resources site.