

Course Syllabus

18-349/14-642: Introduction to Embedded Systems
Spring 2020

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Class Lecture:

Section A: Tuesday and Thursday, 10:30am – 11:50am, HH B131

Course Description:

This practical, hands-on course introduces the various building blocks and underlying scientific and engineering principles behind embedded real-time systems. The course covers the integrated hardware and software aspects of embedded processor architectures, along with advanced topics such as real-time, resource/device and memory management. Students can expect to learn how to program with the embedded architecture that is ubiquitous in cell-phones, portable gaming devices, robots, PDAs, etc. Students will then go on to learn and apply real-time principles that are used to drive critical embedded systems like automobiles, avionics, medical equipment, the Mars rover, etc. Topics covered include embedded architectures (building up to modern 16/32/64-bit embedded processors); interaction with devices (buses, memory architectures, memory management, device drivers); concurrency (software and hardware interrupts, timers);

real-time principles (multi-tasking, scheduling, synchronization); implementation trade-offs, profiling and code optimization (for performance and memory); embedded software (exception handling, loading, mode-switching, programming embedded systems). Through a series of laboratory exercises with state-of-the-art embedded processors and industry-strength development tools, students will acquire skills in the design/implementation/debugging of core embedded real-time functionality.

Number of Units: 12

Pre-requisites: 18-240 and 18-213 (Grade of D or higher is required in the prerequisites)

Anti-requisites for: 18-342 and 18-348

Undergraduate Course Designation: Breadth, Depth, Coverage

Undergraduate Course Area: Computer Hardware

Reference Books and Materials:

Recommended references (not required) for background information:

Hermann Kopetz, *“Real-Time Systems: Design Principles for Distributed Embedded Applications”*. Kluwer, 1997 (ISBN: 978-1441982360)

Jon S. Wilson, *“Sensor Technology Handbook”*, Newnes, 704 pages, 2004. (ISBN: 978-1493303007)

Edward A. Lee and Sanjit A. Seshia, *Introduction to Embedded Systems, A Cyber-Physical Systems Approach*, Second Edition, MIT Press, 2017. (ISBN: 978-0-262-53381-2)

Course Canvas:

To access the course canvas from an Andrew Machine, go to the login page at: <https://canvas.cmu.edu/>. You should check the course canvas daily for announcements and handouts.

Course Wiki:

Students are encouraged to use the ECE wiki to provide feedback about the course at: <http://wiki.ece.cmu.edu/index.php>.

Grading:

60% Lab Assignments (Lab 0=5%, Lab 1=5%, Lab2=10%, Lab 3=15%, Lab 4=20%, Lab 5=5%)

5% Homeworks

15% Midterm

20% Final

While lower cutoffs may be used, the following maximum grade cutoffs are guaranteed:

> 90 A

> 80 B

> 70 C

> 60 D

Handing in Late Assignments:

The penalty for late assignments is 15% per day. Each student will receive a budget of five grace days for the course. These grace days are provided to allow you to cope with most emergencies that prevent completing a lab on time, including computer problems, a cold, getting stuck at the airport, etc.

Here is how grace days work:

- Each assignment has a maximum of two grace days unless otherwise specified in the assignment writeup (for lab 3 and 4 we typically allow more).
- Grace days are applied automatically until you run out.
- If your last hand in is one day late, and you have at least one remaining grace day, then you will receive full credit for the lab and automatically spend one grace day. For example, if an assignment is due at 11:59pm on Thursday and your last hand in is noon on Friday, then you will receive full credit and spend one grace day.
- Once you have spent your grace days, or exhausted the limit for the assignment in question, then you will receive a penalty of 15% for each subsequent late day. For example, suppose you have only one grace day left. If an assignment is due at 11:59pm on Thursday and your last hand in is noon on Saturday, then you will spend your one remaining grace day and be penalized 15%. If your last hand in is noon on Sunday, then you will spend one grace day and be penalized 30%.

Grace days are a tool to allow you to manage your time in the face of personal issues and to help smooth out burstiness in assignment due dates across classes. They are for when you are sick, when a short-term emergency situation arises, when you have too many deadlines all at once, etc. Except for serious persistent personal issues (see below), you should not anticipate additional deadline leniency. We strongly recommend that you conserve your grace days, saving them for the more difficult assignments at the end of the term.

Dealing with Serious Persistent Personal Issues:

We hope that everyone will remain happy and healthy. But, if you have a serious persistent personal issue, such as being hospitalized for an extended period or needing to leave the country for a family matter, please talk to your academic advisor as soon as possible. Such issues consistently affect one's ability to succeed in all classes, rather than just 18-349/14-642, and the academic advisors are equipped to coordinate plans for dealing with them. We will cooperate with such plans, but we cannot construct them independently of the academic advisors. Please contact your course instructor if you are unable to keep up with the course due to a serious personal issue.

Education Objectives (Relationship of Course to Program Outcomes):

(a) an ability to apply knowledge of mathematics, science, and engineering:

This course consists of a series of lectures that contain both practical as well as theoretical engineering underpinnings that are directly applied in laboratory exercises. For example, the course covers real-time scheduling theory and then shows how it is

applied in the development of a real-time operating system that the students develop in a lab.

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability:

This course discusses many of the most important constraints on modern embedded systems. For example, there is both lecture and lab content that covers modeling battery life and timing requirements.

(d) an ability to function on multi-disciplinary teams:

A significant lab exercise in this course requires the students to work in teams.

(e) an ability to identify, formulate, and solve engineering problems:

The labs in this class have multiple open-ended design challenges such as the implementation of operating system components and real-time controllers.

(f) an understanding of professional and ethical responsibility:

A series of lectures in this course covers the topic of safety-critical system design. This also includes a discussion of the ethical implications of design choices.

(j) a knowledge of contemporary issues:

The topic of embedded systems is extremely timely with the current interest in Internet-of-Things technologies.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:

The class requires the use of modern source control, compilers and embedded sensors.

ECE Academic Integrity Policy

(<http://www.ece.cmu.edu/programs-admissions/masters/academic-integrity.html>):

The Department of Electrical and Computer Engineering adheres to the academic integrity policies set forth by Carnegie Mellon University and by the College of Engineering. ECE students should review fully and carefully Carnegie Mellon University's policies regarding Cheating and Plagiarism; Undergraduate Academic Discipline; and Graduate Academic Discipline. ECE graduate student should further review the Penalties for Graduate Student Academic Integrity Violations in CIT outlined in the CIT Policy on Graduate Student Academic Integrity Violations. In addition to the above university and college-level policies, it is ECE's policy that an ECE graduate student may not drop a course in which a disciplinary action is assessed or pending without the course instructor's explicit approval. Further, an ECE course instructor may set his/her own course-specific academic integrity policies that do not conflict with university and college-level policies; course-specific policies should be made available to the students in writing in the first week of class.

This policy applies, in all respects, to this course.

CMU Academic Integrity Policy (<http://www.cmu.edu/academic-integrity/index.html>):

In the midst of self-exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.

This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

This policy applies, in all respects, to this course.

The Carnegie Mellon Code

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.

As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Cheating

(<http://www.cmu.edu/academic-integrity/cheating/index.html>) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Plagiarism

(<http://www.cmu.edu/academic-integrity/plagiarism/index.html>) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

- Text, either written or spoken, quoted directly or paraphrased.
- Graphic elements.
- Passages of music, existing either as sound or as notation.
- Mathematical proofs.
- Scientific data.
- Concepts or material derived from the work, published or unpublished, of another person."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Unauthorized Assistance

(<http://www.cmu.edu/academic-integrity/collaboration/index.html>) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help

provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

- Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
- Submission of work completed or edited in whole or in part by another person.
- Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
- Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
- Use of unauthorized devices.
- Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Research Misconduct

(<http://www.cmu.edu/academic-integrity/research/index.html>) states the following:

According to the University Policy For Handling Alleged Misconduct In Research, "Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research."

The policy goes on to note that "misconduct means:

- fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;
- material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or
- failure to meet other material legal requirements governing research."

"To be deemed misconduct for the purposes of this policy, a 'material failure to comply with Federal requirements' or a 'failure to meet other material legal requirements' must be intentional or grossly negligent."

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

This policy applies, in all respects, to this course.

The Most Important things: Well-Being and Happiness

- Please take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, getting enough sleep, and taking some time to relax. Making those investments will help you achieve your goals and cope with stress.
- All of us benefit from support during times of struggle. You are not alone. If you have a problem, or think you might have a problem, and you don't know what to do, please ask for advice or support.
- If you, or anybody you know, need advice or support, please reach out to people you trust, e.g. friends, family members, faculty members, program administrators, academic or life staff members, RAs or housefellows, professional counselors, clergy, etc.
- [CMU's Counseling and Psychological Services \(CaPS\)](#) is available by phone (412-268-2922) 24 hours a day, seven days a week, year-round. If you're not sure whether a particular problem is a "CaPS Problem", it is certainly worth the call to them to find out. If it isn't, they'll help you to find the right resources or to let you know that it'll work out. CaPS is committed to confidentiality.
- If you would prefer to speak with somebody not associated with CMU, you can call the [re:solve Crisis Network](#) at 888-796-8226.
- If you face a serious emergency, please call the police. Unlike the police in some communities and many countries, the CMU and Pittsburgh Police are highly trained, experienced first-responders able to support members of the community and take the initial steps in responding to any type of crisis or emergent event.
- The CMU police can be reached at 412-268-2323. If you are off-campus, you can dial 9-1-1.
- If you, or somebody you know, needs advice or support, you can get started with a phone call to any of the faculty or student-facing staff at the University —or by saying, "Hi, I think I'd like some advice".