Course Syllabus

18-549: *Embedded Design*
Spring 2015

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Course Description:

This course comprises a semester-long project experience geared towards the development of skills to design realistic and practical embedded systems and applications. Students will work in teams on an innovative project that will involve the hands-on design, configuration, engineering, implementation and testing of a prototype of an embedded system of their choice. Students will be expected to leverage proficiency and background gained from other courses, particularly with regard to embedded real-time principles and embedded programming. The project will utilize a synergistic mixture of skills in system architecture, modular system design, software engineering, subsystem integration, debugging and testing. From inception to demonstration of the prototype, the course will follow industrial project practices, such as version control, design requirements, design reviews and quality assurance plans. The initial lecture content will cover background material intended to complement the project work. The remainder of the course will consist of regular team presentations of key project milestones, current project status, a final project presentation and functional demonstrations of various subsystems, even as the entire prototype is being developed.

A primary objective of this course is to provide the engineering student with a cooperative working experience as an active member of an interdisciplinary team. Students obtain practical experience with the design process and both learn and reinforce their knowledge of specific technical topics covered in lecture and applied in the project. A structured framework is provided to aid in the success of the team. In the second half of the semester, the teams meet weekly with the instructors to discuss progress, challenges, issues and plans.

Number of Units: 12

Pre-requisites: (18320 or 18447 or 15410 or 18370 or 18491) and (18349 or 18348). For undergraduate ECE students: Senior design or equivalent. CMU students (excluding undergraduate ECEs and MEs) may take the course upon slot availability with permission of the instructors.

Undergraduate Designations: Coverage, Depth, Capstone Design

Undergraduate Course Area: Computer Hardware

Class Schedule:

- **Lecture**: *Mondays & Wednesdays: 12:00p.m. – 1:20 p.m., MM 103*
- **Lab**: *Available 24/7 HH 1303*

Required Textbook: None

Brief list of topics covered: Embedded Design, Microcontrollers, Sensors, Actuators

Course Blackboard: To access the course blackboard from an Andrew Machine, go to the login page at: http://www.cmu.edu/blackboard. You should check the course blackboard daily for announcements and course materials and information.

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

Tentative Course Calendar:

Wk.	Date	Day	Topics	Assignment/Activity	Due Date
January					
1	14	W	Lecture 1: Course Introduction	Task 0: Teaming info document	Tuesday, 1/21
2	19	M	Martin Luther King Day-No class		
	22	W	Lecture 2: Project Overview	Team formation complete Task 1: Lab 1 goes out	2/2
3	26	M	Lecture 3: PCB design		
	28	W	Lecture 4: Sensors and Actuators		
February					
4	2	M	Lecture 5: Communications	Lab 1 Due	
	4	W	Lecture 6: Low-Power Embedded		
5	9	M	Lecture 7: Embedded OS	Task 2: Lab 2 goes out	2/18
	11	W	Team Meetings	Task 4: Design concept proposal Due [document]	2/11
6	16	M	Proposal Presentation #1		
	18	W	Proposal Presentation #2	Lab 2 Due Task 3: Lab 3 goes out	3/2
	20	F	Lab: Lab 2 Demo, Website Check 1	Task 17.1: Website Check 1	2/20
7	23	M	Lab: demo Lab 2		
	25	W	Team Meetings	Task 6: System demo #1	3/16
March					
8	2	M	Lab: demo Lab 3	Lab 3 Due	
	4	W	Lecture 8: Ethics		
	5	Th	Peer evaluation #1	Task 7: Peer evaluation #1	3/5
9	9	M	Spring Break; No Classes		
	11	W	Spring Break; No Classes		
10	16	M	Lab: project demo #1		
	18	W	Team Meeting	Task 8: System demo #2	3/23
11	23	M	Lab: project demo #2		
	25	W	Team Meeting	Task 9: System demo #3	3/30
12	30	M	Lab: project demo #3		
April					
12	1	W	Team Meeting	Task 10: System demo #4	4/6
	3	F	Website Check 2	Task 17.2: Website Check 2	4/3
13	6	M	Lab: project demo #4		
	8	W	Team Meeting	Task 11: System demo #5	4/13
14	13	M	Lab: project demo #5		
	15	W	Team Meeting	Task 12: System demo #6	4/20
15	20	M	Lab: project demo #6		
	22	W	Lab: Final system demo	Task 13: Final system demo	4/22

16	27	M	Course feedback session		
	29	W	Lab: Final system demo encore	Task 13: Final sys demo encore	4/29
May					
17	6	W	Public presentation (Final Exams May 4-12)	Task 14: Public presentation	5/6
	8	F	Final Report	Task 15: Final report	5/8
	9	S	Peer evaluation #2	Task 16: Peer evaluation #2	5/9
18	11	M	Website Check 3	Task 17.3: Website Check 3	5/11

Course Assignments and Grading:
Because this is a Capstone Design Course, grading is based on your ability to

- Function on a multidisciplinary team
- Apply your accumulated knowledge within your discipline (Electrical and Computer Engineering, Computer Science)
- Design your system under real constraints of time and overall cost
- Be proactive in designing, planning and implementing a successful project
- Identify issues, propose solutions, and iterate as problems arise
- Apply engineering tools and methodologies for project completion
- Communicate thoroughly, clearly and concisely in demonstrations, presentations and reports

Assessment of these metrics occurs through a series of assignments ("tasks"). Tasks include the design proposal, a mid-semester design presentation, a final comprehensive report, weekly subsystem demonstrations in the first half of the semester and weekly incremental demonstrations of the full system under development in the second half of the semester. At the end of the semester, teams give a public demonstration of their final project. This task is graded on presentation values.

Subsystems and systems for each team naturally differ, since they depend on the specific design of the team. Therefore, basic tasks likely to be relevant for all teams are given for the 2-3 initial lab assignments in the first half of the semester. Each team must identify how to best incorporate the task into their project, or can petition to perform some equally challenging task. Goals for subsystem demonstrations thereafter are set by each team, with feedback and approval by the instructors.

All lab demonstrations except the final one (Tasks 3-6 and 9-13 below) (hereafter "system demos") are 15 min. long and comprise a short (5-7 min.) presentation of progress to the instructors by one of the team members, with remaining time spent in discussion with the entire team. Team members rotate each week in taking a turn at presenting. All team members are expected to attend their team's demonstrations; students who miss demonstrations without having arranged ahead of time with the instructors to do so for a valid reason receive a zero for the lab. The lowest score for the system demos is dropped from total grading to make up for a possible bad day.

Each system demo is accompanied by an Individual Lab Report (ILR), generated by each individual team member. The ILR should be 1 to 2 pages of 12-point text, 1" margins, with at least one figure, but with no limit on figures. The ILR provides the individual's progress, challenges/issues, and plans, and cross-references work and interactions with teammates. Documentation includes system functionality, technical understanding of issues, and tangible progress on system implementation, with emphasis on your individual contributions. Teams are encouraged to coordinate content for their ILRs, but the writing must be done by each individual. Students must post ILRs electronically to Blackboard by 11:59 p.m. CMU Blackboard time on the day after the system demo, with a ½-off penalty for late submissions within 12 hours and zero credit after that. Upon submission, place the ILR in the Documents section of your team's website for later reference by all team members.

TASK	POINTS	DUE DATE	DESCRIPTION
0 Teaming info spreadsheet	0	1/21	Background info to facilitate team-forming
1 Platform Lab 1	15	2/2	PCB Design
2 Platform Lab 2	15	2/18	Assembly and Bring up
3 Platform Lab 3	15	3/2	Firmware
4 Project Proposal Document	15	2/11	Concept, specifications, and milestones
5 Project Proposal Presentation	10	2/16-2/18	In-class presentation of Project
17.1 Website check 1	6	2/20	First website check
5 First system demo	10	3/16	First system/subsystems demonstration
6 Peer evaluation	10	5/1	Anonymous peer evaluation by teammates
7 Second system demo	10	3/23	Second system/subsystems demonstration
8 Third system demo	10	3/30	Third system/subsystems demonstration
9 Fourth system demo	10	4/6	Fourth system/subsystems demonstration
17.2 Website check 2	6	4/3	Second website check
10 Fifth system demo	10	4/13	Fifth system/subsystems demonstration
11 Sixth system demo	10	4/20	Sixth system/subsystems demonstration
12.1 Final system demo	40	5/2-5/3	Final full system demonstration
13 Public demonstration	10	5/8	Public project description and demonstration
14 Final report	20	5/12	Comprehensive final report
15 Website check 3	8	5/12	Third website check
TOTAL POINTS	**230**	→	**230 minus (lowest score dropped among Tasks 5-9, 10-11)**

Unlike the ILRs, the final report is a comprehensive team-written report. Submit the final product in .pdf format. The mid-semester presentation (Task 7) is a 15-min. verbal, Power point-supported team presentation delivered in class to the instructors and classmates. Content and format for the design proposal (Task 1), mid-semester presentation (Task 7), and final report (Task 17) will be posted on Blackboard and explained in class.

Tasks with point totals are summarized in the table above. Individual grading of Tasks 5-9, 10-11 is based on the ILR and on the lab presentation & demonstration. The 40 points for the final system demonstration are allocated among basic (subsystem) functionality, advanced (integrated) functionality, robustness and agility, and "coolness" factors

Project Website

We require that your team create and maintain a project website. The required website content is detailed in a document on Blackboard under Course Documents→Assignments Guidance→Website Guide. The website material should be updated and refined over the course of the semester, and that document provides a timeline with various associated milestones. The website must have a Documents section that is comparable to a laboratory workbook. It should be a living documentation of the team's work on the tasks and project and is a collection of notes, papers, datasheets, schematics, code, flowcharts, and documentation that evolves over the course of the semester. Documents are updated as changes are made. A log of changes and why they are made is required.

The website will be reviewed by the instructors at three times during the semester (worth respectively 6, 6, and 8 points) for a total of 20 points. The grading checkpoints will occur between the third week of class and the first week of finals. Additional checks may be made in order to give feedback unassociated with a grade. A good website with an updated Documents section will make it easier to write the team's final report.

Policy on Late Assignments

No credit is given for unexcused absences from demonstrations or for late reports. See Course Assignments and Grading above for details. Dropping the low score provides a mechanism for uniformity and fairness in these cases.

Teams and Selection

Students roughly break down into 3 different skill sets: computer engineers or computer scientists (programming), electrical engineers (electronics, sensing, and control), and mechanical engineers (mechanisms and control). You should form teams consisting of at least one student from each of these skill set areas. Until 2009, 3-person teams were the standard; given higher enrollment since 2009, we went to 4-person teams, and this will almost certainly also be the case this year.

Laboratory

Teams have 24/7 access to HH 1303 via card access. The lab has sixteen stations, each with a PC and power supply. Oscilloscopes, meters, and test equipment are shared among the stations. Small tools are available for use in designated areas of the laboratory.

Purchasing and Reimbursements

A guideline reimbursable limit for the total parts and materials cost purchased by the team is $700; however, each team will create a proposed budget and negotiate a final reimbursable project cost with the instructors. Each team may scavenge parts worth up to an additional $200 plus the amount of any underspending on the $700 baseline. Reasonable estimates of the value of scavenged parts should be made. Finally, each team may spend up to $100 out of its own pocket unreimbursed. This brings the guideline totals for the project to $700 reimbursable and $1000 total value. At the end of the semester, the instructors keep all parts supplied or reimbursed. These will be available for students in succeeding years.

Department policy is that students in the course will not make (reimbursable) purchases. Parts will instead be ordered on a regular basis by a member of the ECE staff. Teams will post the parts they want to purchase in an on-line spreadsheet according to a procedure we will make available on Blackboard.

In the early labs, we will provide teams with microcontrollers, motors, sensors, and some low-cost parts. If you want ultimately to use any of these parts in your project, include their value against the $700 baseline total. Some electronic parts can be obtained from the ECE Electronic Stock Room (HH 1301), or purchased from local electronic parts stores, or from mail-order suppliers. See the vendor list under Course Documents→Purchasing on Blackboard for suggestions on where to shop for parts.

Responsibilities of the Students
If you are not serious about taking this course, please drop it immediately – the wait list is long. Students that drop the class late in the semester affect their team's progress. In the event of late drops or unavoidable problems, the instructors try to compensate by adjusting the metrics for grading.

Each group works independently of other groups, although cross-pollination of design ideas tends to occur naturally. Each member of each group assumes an equitable portion of the technical tasks. Technical tasks include all aspects of design, including report writing. Although gathering of information or materials for design or prototype are important, by themselves such tasks are not considered technical and therefore will not be counted as satisfactory workload. Each student is graded individually. Therefore, each student is required to be involved in a meaningful way in the engineering tasks involved at each stage of the design process, starting from concept development, to prototype, to testing, to communication of the results.

Team members are selected based on various skills. Each member has basic responsibilities to the team. These responsibilities include timely attendance in class and at pre-scheduled out-of-class group meetings and active involvement in all assigned tasks. Individuals are expected to help others on their team learn and participate in their area of expertise. In particular, individuals must demonstrate a willingness to cross disciplinary boundaries and provide effort on mechanical, electrical, and programming/control aspects of tasks. Individuals are not to focus completely on their area of expertise with little regard to the other complementary mechatronic areas. If there is an irreconcilable problem within your team, you must bring it to the instructors' attention as soon as possible.

Each team member has the responsibility to ensure that documentation in the team's Lab Workbook is updated, comprehensive and accurate.

Attendance in class is mandatory. In case of difficulties among the group members which cannot be handled by the group members, inform the instructors promptly. Waiting until the end of the term to bring up such problems is too late.

Education Objectives (Relationship of Course to Program Outcomes)
(a) an ability to apply knowledge of mathematics, science, and engineering:
This is addressed by the following course activities: design of the project; implementation of the project; and iterative design adjustments based on instructor feedback, evaluation, and team interactions.

(b) an ability to design and conduct experiments, as well as to analyze and interpret data:
The evaluation part of the course involves defining and running experiments on the designed devices and analyzing and explaining the results. Typical examples are testing and characterizing the accuracy of a linear drive based on a rotary motor or the repeatability of a pneumatic pancake-flipper.

(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:

The design component of the course specifically addresses this criterion. Of the factors mentioned, those which are regularly considered are economic ($250-350 budget limit), health and safety, manufacturability, and sustainability. The degree to which the other factors mentioned are addressed by a team depends on the project. Some of these issues also come up during the design mock-up and mid-semester presentations and during weekly status meetings with the instructors.

(d) an ability to function on multi-disciplinary teams:
Projects are team-based. Because recent enrollments have been between 40 and 55 students, most teams have four students, with some teams having three, depending on the divisibility by four of the total number of students enrolled.

(e) an ability to identify, formulate, and solve engineering problems:
This criterion is addressed by the design and implementation components of the course. Students are given a desired system functionality, such as automatic pancake-flipping or M&M sorting, and performance specifications such as size and speed. They then design a system that has the components necessary to realize the functions and performance specifications, and iteratively build and test the system.

(f) an understanding of professional and ethical responsibility:
This topic is discussed in the first lecture and then raised as needed throughout the semester. Typical examples are: setting and meeting milestones (both advertised project deadlines and personal deadlines for coordination with teammates), meeting attendance expectations, documenting contributions of individual team members, giving credit in documents (e.g. through citations), and reporting results truthfully.

(g) an ability to communicate effectively:
Each team gives four presentations (design mock-up, mid-semester status, final lab system demo, and public presentation) and ten subsystem demos in the lab. Primary presenters for subsystem demos are designated in round-robin fashion from week to week. Each team also writes two major documents (design proposal and final report), and each student writes ten weekly individual lab reports. Finally, starting about halfway through the semester, teams meet weekly with the instructors for an interactive discussion on status.

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context:
Students are asked in their final report to comment on how their design would need to be modified in order to be appropriate as a product provided by a spin-off company. This raises economic and sometimes societal issues. Environmental issues are sometimes touched on indirectly, e.g., use of batteries vs. wall power, power efficiency.

(i) a recognition of the need for, and an ability to engage in life-long learning:
The projects require students to learn about new material in their own main disciplines (ME - mechanism, ECE - electronics, or CS - programming), and we encourage cross disciplinary learning and activity to increase the educational benefits and likelihood of project success. This sets an example for the need for life-long learning.

(j) a knowledge of contemporary issues:
An early lecture includes a review of patents related to the project. The design proposal typically requires teams to examine existing partial or full solutions to the project challenge and evaluate

them in the light of available resources, materials, power budget, and programming tools. The final report requires consideration of how the project or a variant of it might meet contemporary societal needs.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:
These skills are addressed through the implementation and evaluation components of the course.

Academic Integrity Policies:

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.

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.