ECE 461/561 Course Syllabus

ECE 461/561 – Embedded System Optimization

ECE 461 Section 001

ECE 561 Sections 001, 601 (Engineering On-Line)

Spring 2025

3 Credit Hours

Special Notes

This is a dual level course. Students in ECE 561 will be required to develop more complex programs, perform more detailed system analysis and complete more challenging tests than those in ECE 461. Performance on classwork will be evaluated more rigorously for ECE 561 students.

Course Description

Analysis and optimization of embedded computer systems, covering speed, responsiveness, power, energy and memory requirements. Course uses hardware from ECE 460/560 – Embedded System Architectures.

Learning Outcomes

By the end of this course, students should be able to:

- Evaluate a program's **speed** by profiling its execution time distribution and identifying hot functions.
    - Analyze function object code to evaluate efficiency and compiler effectiveness and identify deficiencies.
    - Improve program speed by tuning software toolchain, optimizing code and algorithms.
- Profile a program's **memory requirements** and identify largest components.
    - List, explain, apply, synthesize and evaluate methods to reduce program's memory requirements.
- List, explain and apply **real-time system** concepts.
    - Analyze task response times and schedulability for a real-time system.
    - List, explain, and apply different scheduling and prioritization methods to meet timing goals.
    - List, explain and analyze impact of modern computer microarchitecture features on real-time performance.
- List, explain and apply **power and energy** concepts for digital, linear and power circuits.
    - Analyze an embedded system's power and energy consumption.
    - Design and optimize an embedded system to meet low power or low energy requirements.

Course Structure

There are two scheduled 75-minute classes per week. This course will typically use a flipped lecture structure. The module schedule pages on the course's WordPress site indicate each day's activities.

- Some topics will be covered by a traditional lecture during the class time.
- A flipped approach will be used for other topics. Before the scheduled class time, students will prepare by watching online videos or completing reading assignments. Some video lectures may have Panopto quizzes embedded, so be sure to watch these before class.
- The scheduled class time may also be used for discussions and demonstrations.
- Be sure to attend each class or watch the scheduled class recording promptly. Some critical information (e.g., quiz announcements) may be repeated as Moodle or Piazza announcements for your convenience, but it is your responsibility to keep up to date on the class recordings (as well as flipped lectures and reading assignments).
- We will use Moodle forums for discussions.

Course Policies

All homeworks are to be completed on the student's time and submitted electronically via Moodle. There are no scheduled lab sessions.

Students are to work individually unless otherwise announced (on a per-assignment basis).

Online class evaluations will be available for students to complete during the last 2 weeks of the semester. Evaluations then become unavailable at 8 am on the first day of finals for full semester courses and the last day of classes for shorter session courses.

Students will receive an email message directing them to a website where they can login using their Unity ID and complete evaluations. All evaluations are confidential; instructors will not know how any one student responded to any question, and students will not know the ratings for any instructors.

Evaluation website: http://go.ncsu.edu/cesurvey
Student help desk: classeval@ncsu.edu
More information about ClassEval

Instructors

Alexander Dean - *Instructor*
Email: agdean@ncsu.edu
Web Page: http://people.engr.ncsu.edu/agdean

Instructor Office Hours:

Section 001: In 2104 EB2 shortly after class until 5:00 PM and also by appointment. An office hour may be cancelled if the class immediately before ends early (e.g. due to all questions being answered).

Section 601 (Engineering Online): By Zoom (link to be announced on Moodle) on ***Monday and Wednesday time TBD*** (when requested) or by appointment.

Skieler Capezza – *Teaching Assistant for ECE 461/561*
Email: srcapezz@ncsu.edu
Office Hours: To be announced on Moodle

Course Meetings

Lecture

Days: MW
Time: 3:00pm
Campus: Centennial
Location: 4134 FWH
This meeting is required.

Course Materials

Textbooks

Embedded Systems Fundamentals with ARM Cortex-M Microcontrollers - *Alexander G. Dean*
Edition: 1st
ISBN: 978-1911531036
Web Links: Book website, Arm University GitHub (for pdf), Amazon
Cost: Free PDF, or printed copy for ~$40
This textbook is required.

Embedded System Design, Analysis and Optimization - *Alexander G. Dean*
Edition: 1st
ISBN: 978-1-935772-96-5
Web Link: https://people.engr.ncsu.edu/agdean/Books/Dean_ESDAO_RL78_dist.pdf
Cost: $0
This textbook is required.

Better Embedded System Software - *Philip Koopman*
Edition: 1st
ISBN: 9870984449002
Web Link: http://betterembsw.blogspot.com

Cost: $50
*This textbook is **optional**.*

Expenses

None.

Materials

Digilent Analog Discovery 2 or 3 Test Equipment and the free Waveforms program or similar scope/logic analyzer are required. The AD2/3 are strongly recommended, as the expansion shield plugs in directly to the AD, simplifying development. The AD capabilities include an oscilloscope and logic analyzer. discounted price of $249 is available for students who qualify for academic pricing (https://digilent.com/shop/academic/). Check with the instructor if you wish to use a different device.
This material (or equivalent) is required.

Digital Multimeter - $20
This material is optional.

Requisites and Restrictions

Prerequisites

C- or better in ECE 460/560 - Embedded Systems Architectures, or consent of instructor.

Co-requisites

None.

Restrictions

Credit will not be awarded for both ECE 461 and ECE 561.

General Education Program (GEP) Information

GEP Category

This course does not fulfill a General Education Program category.

GEP Co-requisites

This course does not fulfill a General Education Program co-requisite.

Transportation

This course will not require students to provide their own transportation. Non-scheduled class time for field trips or out-of-class activities is NOT required for this class.

Safety & Risk Assumptions

None.

Coronavirus

Due to the COVID-19 pandemic, public health measures continue to be implemented across campus. Students should stay current with these practices and expectations through the Protect the Pack website (https://www.ncsu.edu/coronavirus/). The sections below provide expectations and conduct related to COVID-19 issues.

Health and Participation in Class

We are most concerned about your health and the health of your classmates and instructors/TAs.

- If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus, you should not attend any face-to-face (F2F) classes or face-to-face component of a hybrid class. Work with your instructor on any adjustments necessary; also follow other university guidelines, including self reporting (Coronavirus Self Reporting): Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
- If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to a F2F class or activity.

- If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to make alternative plans, as necessary.
- If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor.

Health and Well-Being Resources

These are difficult times, and academic and personal stress are natural results. Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:

- Counseling Center (NCSU Counseling Center)
- Student Health Services (Health Services | Student)
- If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: (Share a Concern).
- If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program (Pack Essentials).

Community Standards related to COVID-19

We are all responsible for protecting ourselves and our community. Please see the community standards and Rule 04.21.01 regarding Personal Safety Requirements Related to COVID-19 RUL 04.21.01 – Personal Safety Requirements Related to COVID-19 – Policies, Regulations & Rules

Course Expectations Related to COVID-19:

- **Face Coverings:** All members of the NC State academic community are expected to follow all university policies and guidelines, including the Personal Safety Rule and community standards, for the use of face coverings.
- **Course Attendance**: NC State attendance policies can be found at: REG 02.20.03 – Attendance Regulations – Policies, Regulations & Rules. Please refer to the course's attendance, absence, and deadline policies for additional details. If you are quarantined or otherwise need to miss class because you have been advised that you may have been exposed to COVID-19, you should not be penalized regarding attendance or class participation. However, you will be expected to develop a plan to keep up with your coursework during any such absences. If you become ill with COVID-19, you should follow the steps outlined in the health and participation section above.
- **Technology Requirements:** This course may require particular technologies to complete coursework. Be sure to review the syllabus for these expectations, and see the syllabus technical requirements for your course. If you need access to additional technological support, please contact the Libraries' Technology Lending Service: (Technology Lending).

Course Delivery Changes Related to COVID-19

Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course could change accordingly, including from in-person to remote. Regardless of the delivery method, we will strive to provide a high-quality learning experience.

Need Help?

If you find yourself in a place where you need help, academically or otherwise, please review these Step-by-Step Help Topics. In addition, the following College of Engineering individuals are very available to assist students with any matter, please reach out to them:

-Dr. Laura Bottomley, Women and Minority Engineering Program, laurab@ncsu.edu

-Ms. Angelitha Daniel, Women and Minority Engineering Program, aldaniel@ncsu.edu

-Dr. David Parish, COE Assistant Dean, dwparish@ncsu.edu

-Dr. Jerome Lavelle, COE Associate Dean, jplavell@ncsu.edu

Other Important Resources

- **Keep Learning:** Keep Learning
- **Protect the Pack FAQs:** Frequently Asked Questions | Protect the Pack
- **NC State Protect the Pack Resources for Students:** Resources for Students | Protect the Pack
- **Academic Success Center** (tutoring, drop in advising, career and wellness advising): Academic Success Center.
- **NC State Keep Learning, tips for students opting to take courses remotely:** Keep Learning Tips for Remote Learning
- **Introduction to Zoom for students:** https://youtu.be/5LbPzzPbYEw
- **Learning with Moodle, a student's guide to using Moodle:** https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226
- **NC State Libraries** Technology Lending Program

Grading

Grade Components

Component	Weight	Details	
		In-Person Course: Sections -001	**EOL Course: Section 601**
Homework	70%	Student completes assignment, submits report and data for grading. Students must work and submit individually. Five homework assignments are planned.	
Class Preparation	5%	Prepare by watching flipped lecture videos before class.	Prepare by watching flipped lecture videos before 23:59:59 of first Sunday following class.
Class Attendance	5%	Attend class and sign attendance sheet, or watch class video recording within 24 hours of class completion.	Watch class video recording before 23:59:59 of first Sunday following class.
Final Exam	20%	Student completes a comprehensive in-class paper final examination (April 25, 2025, 3:30 – 6:00 PM).	Proctored paper final examination for 2.5 hours in 72 hour window starting April 25, 2025.
Class Eval Completion	3% extra credit	If at least 70% of the students in a course section complete the Class Eval survey, then all students in that section will get this extra credit.	If at least 70% of the students in section complete the Class Eval survey, then all students in that section will get this extra credit.

Letter Grades

This Course uses Standard NCSU Letter Grading:

97	≤	**A+**	≤	100
93	≤	**A**	<	97
90	≤	**A-**	<	93
87	≤	**B+**	<	90
83	≤	**B**	<	87
80	≤	**B-**	<	83
77	≤	**C+**	<	80
73	≤	**C**	<	77
70	≤	**C-**	<	73
67	≤	**D+**	<	70
63	≤	**D**	<	67
60	≤	**D-**	<	63
0	≤	**F**	<	60

Requirements for Credit-Only (S/U) Grading

Performance in research, seminar and independent study types of courses (6xx and 8xx) is evaluated as either "S" (Satisfactory) or "U" (Unsatisfactory), and these grades are not used in computing the grade point average. For credit only courses (S/U) the requirements necessary to obtain the grade of "S" must be clearly outlined.

Requirements for Auditors (AU)

Information about and requirements for auditing a course can be found at http://policies.ncsu.edu/regulation/reg-02-20-04.

Policies on Incomplete Grades

If an extended deadline is not authorized by the Graduate School, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) by the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at http://policies.ncsu.edu/regulation/reg-02-50-03. Additional information relative to incomplete grades for graduate students can be found in the Graduate Administrative Handbook in Section 3.18.F at http://www.fis.ncsu.edu/grad_publicns/handbook/

Late and Missing Assignments

Late homework submissions will be accepted until **23:59:59 April 24, 2025**, or until a solution is posted (whichever comes first).

There is an immediate 5% penalty for missing the deadline, and then an additional 2% penalty per 24 hours late (prorated). The maximum late penalty is capped at 30% to encourage completion of the projects despite missing the deadline. These penalties may be reduced or waived based on extenuating circumstances; contact the instructor if needed.

Attendance Policy

For complete attendance and excused absence policies, please see http://policies.ncsu.edu/regulation/reg-02-20-03

Attendance Policy

Full participation in classes, assignments and examinations is expected of all students. Attendance of all lectures is strongly encouraged but will not be tracked. It's much easier to do well in a course if you attend each lecture, pay attention and take notes. Every lecture you miss will hurt your performance.

Be sure to attend each class or watch the scheduled class recording promptly. Some critical information (e.g., quiz announcements) may be repeated as Moodle announcements for your convenience, but **it is your responsibility to keep up to date on the class recordings** (as well as flipped lectures and reading assignments).

Absences Policy

Excused absences are allowed as described in regulations at http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.3.php. For other situations, please contact the instructor.

Makeup Work Policy

The student should contact the instructor at least a week before an absence to discuss scheduling how to make up missed work.

Additional Excuses Policy

None.

Academic Integrity

Academic Integrity

Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at http://policies.ncsu.edu/policy/pol-11-35-01

Academic Honesty

See http://policies.ncsu.edu/policy/pol-11-35-01 for a detailed explanation of academic honesty.

Honor Pledge

Your signature on any test or assignment indicates "I have neither given nor received unauthorized aid on this test or assignment."

Electronically-Hosted Course Components

Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

Electronically-hosted Components: Please be advised this course is being recorded for current and potential future educational purposes. By your continued participation in this recorded course, you are providing your permission to be recorded.

Accommodations for Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the Disability Resource Office at Holmes Hall, Suite 304, Campus Box 7509, 919-515-7653. For more information on NC State’s policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG02.20.01) (https://policies.ncsu.edu/regulation/reg-02-20-01/).

Non-Discrimination Policy

NC State provides equal opportunity and affirmative action efforts, and prohibits all forms of unlawful discrimination, harassment, and retaliation ("Prohibited Conduct") that are based upon a person's race, color, religion, sex (including pregnancy), national origin, age (40 or older), disability, gender identity, genetic information, sexual orientation, or veteran status (individually and collectively, "Protected Status"). Additional information as to each Protected Status is included in NCSU REG 04.25.02 (Discrimination, Harassment and Retaliation Complaint Procedure). NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at http://policies.ncsu.edu/policy/pol-04-25-05 or https://oied.ncsu.edu/divweb/. Any person who feels that he or she has been the subject of

prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

Course Schedule

NOTE: The course schedule is subject to change. Refer to course website on WordPress for current details.

Introduction

Introduction to course. Microcontroller and peripheral overview. Development tool introduction.

Examining Object Code without Getting Lost

ARM Cortex M ISA introduction. Function call graph, control flow graph. Function prolog, body, epilog. Register use conventions, call stack, interrupt response. Implementation of static, automatic and dynamic memory allocation. Use of disassembly tools.

Analyzing and Optimizing Speed

Application profiling. Tuning the toolchain, low and high-level source code optimizations for speed. Polynomial approximations. Fixed-point math. SIMD programming concepts.

Analyzing and Optimizing Responsiveness

Design and analysis of real-time systems. Use of preemptive real-time kernel. Leveraging hardware peripherals and DMA for responsiveness.

Analyzing and Optimizing Power or Energy Use

Methods to measure energy or power use. Power and energy consumption models for digital CMOS logic. Methods for reducing power or energy use. Use of CPU stop and sleep modes, hardware peripherals (and sleep modes), DMA, voltage and frequency scaling, power supply options, other circuit design choices.

Analyzing and Optimizing Memory Requirements

Methods for analyzing and reducing ROM and RAM size requirements for embedded systems.