

ECE 785 Course Syllabus

ECE 785 – Topics in Advanced Computer Design

Section 001

Spring 2024

3 Credit Hours

Course Description

In depth study of topics in computer design; advantages and disadvantages of various designs and design methodologies; technology shifts, trends, and constraints; hardware/software tradeoffs and co-design methodologies. We specialize in ARM Cortex-A application processors and embedded Linux.

Learning Outcomes

Design, Analysis and Optimization of high-performance embedded systems using ARM application processors and Linux.

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

The last project will be due by the end of the last day of classes.

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

Instructor Office Hours: Immediately after class in 2014 EB2, or by appointment (especially for EOL students). An office hour may be cancelled if the class immediately before ends early (e.g. due to all questions being answered).

Course Meetings

Lecture

Days: TH

Time: 11:45am - 1:00pm

Campus: Centennial

Location: 1230 EB1

This meeting is required.

Course Materials

Textbooks

Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux - Derek Molloy

Edition: 1st

ISBN: 978-1119188681

Web Link: <http://exploringrpi.com/>, may also be available digitally through All-In

Cost: \$25

This textbook is required.

Operating Systems Foundations with Linux on the Raspberry Pi - Professor Wim Vanderbauwhede and Dr. Jeremy Singer

Edition: 1st

ISBN: 978-1-911531-20-3

Web Link: <https://www.arm.com/resources/education/books/operating-systems>

Cost: Free

This textbook is required.

Linux Kernel Programming: A comprehensive and practical guide to kernel internals, writing modules, and kernel synchronization - Kaiwan N. Billimoria

Edition: 2nd

ISBN: 978-1-80323-222-5

Web Link: <https://www.packtpub.com/en-us/product/linux-kernel-programming-9781803241081>

Cost: \$9.99 (eBook), \$49.99 (Paperback)

This textbook is required.

Linux Kernel Programming (Part 2) - Char Device Drivers and Kernel Synchronization - Kaiwan N. Billimoria

Edition: 1st

ISBN: 978-1-80107-951-8

Web Link: [https://github.com/PacktPublishing/Linux-Kernel-Programming/tree/master/Linux-Kernel-Programming-\(Part-2\)](https://github.com/PacktPublishing/Linux-Kernel-Programming/tree/master/Linux-Kernel-Programming-(Part-2))

Cost: Free

This textbook is required.

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.*

If needed, a Raspberry Pi 3B computer will be provided to each group of students for the semester. If you have your own RPi 3B or 4B available, you are encouraged to use it instead.

More detailed information on materials is available on the course website (Building Embedded Systems with Linux/Required Components).

Requisites and Restrictions

Prerequisites

None.

Co-requisites

ECE 561

Restrictions

None.

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](https://www.ncsu.edu/coronavirus/) 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

As a student you may experience a range of personal issues that can impede learning, such as strained relationships, increased anxiety, alcohol/drug concerns, feeling down, difficulty concentrating and/or lack of

motivation. These mental health concerns or stressful events may lead to diminished academic performance and may impact your ability to participate in daily activities. It is very important that you have a support system and that you ask for help when you are struggling. The Counseling Center at NC State offers confidential mental health services for full time NC State students, including same-day emergency services. Please visit <https://counseling.dasa.ncsu.edu/> to get connected.

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](#)).

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
Projects	70%	Multiple (4-6) projects involving programming and/or analysis. May include demonstration, report, and/or oral presentation. Final project is due on last day of classes.
Class Preparation	5%	Watch flipped lecture videos before class.
Class Attendance	5%	Attend class and sign attendance sheet, or watch class video recording within 24 hours of class completion.
Final Exam	20%	Student completes a final examination which is comprehensive but emphasizes (e.g. 2/3) code analysis and optimization. (April 24, 2025, 3:30 – 6:00 PM).
Class Eval Completion	3% extra credit	If at least 70% of the students complete the Class Eval survey, then all students 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 Assignments

Late submissions will be accepted up to two weeks after the due date. 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., 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).

Absences Policy

Absences are allowed but missed work must be made up (see below).

Makeup Work Policy

Students must meet with the instructor before the planned absence to determine 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>

None.

Academic Honesty

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

None.

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: Wolfware website: <http://courses.ncsu.edu/ece785/lec/001/>

Accommodations for Disabilities

Reasonable accommodation will be made for students with verifiable disabilities. In order to take advantage of available accommodation, 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: This is a rough course schedule and is subject to change. Please refer to the schedule on course's WordPress website for the latest details.

Building Embedded Systems with Linux

Platform Introduction

- Introduction
- Comparison with deeply embedded MCUs
- Getting started with the RPi3/RPi4
- ARM ISA and Cortex-A57/-A72
- Frequency Scaling: DVFS and cpufreq

Device Interfacing

- Methods
 - Sysfs, gpiod
- Peripherals
 - GPIO
 - ADC
 - PWM and Timers
 - UART/asynchronous serial
 - I2C
 - SPI
- Timing Analysis

Multithreaded System Design

- Threads and processes
- Communication and synchronization
- Loadable kernel modules: interrupts and kernel threads

Real-Time Systems

- Concepts
- Methods: Seeking real-time performance on the RPi4

Analyzing and Optimizing Speed (and Other Characteristics)

Speed

- Speed performance analysis and profilers
- ARM v8-A Architecture and ARM Cortex-A57/A72
- Toolchain tuning
- Low-level optimization
- High-level optimization
- Advanced SIMD Processing
 - Advanced SIMD instructions and the Neon Unit
 - Compiler vectorization
 - Libraries
 - Intrinsics
 - Assembly code

Power and Energy

- Power use concepts, models and the RPi3/RPi4
- Power measurement