Microprocessor Applications 2

EEL 4745C Section 1-6
Class Periods: MWF 4:05 - 4:55 PM
Location: LAR-330
Academic Term: Fall 2025

Instructor:

Md Jahidul Islam. Email: jahid@ece.ufl.edu
Office Phone Number: 352-392-9510
Office Hours: Thursdays 4:00 - 5.00 PM at Mala-5108

Teaching Assistants:

Please contact through the Canvas website

- Bohdan Purtell (bohdanpurtell@ufl.edu OH: Wednesday 11:45 - 12:35 P.M)
- Sanat Konda (konda.sanat@ufl.edu OH: Tuesdays 11:00 - 12:00 P.M)
- Ahmed Sattar (asattar1@ufl.edu OH: Mondays 11:45 - 12:45 P.M)

Course Description

This course provides a hands-on, systems-level introduction to microprocessor applications with a strong emphasis on real-time operating systems (RTOS) and embedded development. Students begin by exploring the ARM Cortex-M4 architecture, instruction sets, and low-level interfacing using board support packages and integrated development environments, such as Code Composer Studio (CCS). The course then delves into RTOS fundamentals—threads, schedulers, inter-process communication (IPC), synchronization primitives, and deadlock prevention—through the implementation of a custom G8RTOS kernel. Advanced topics include dynamic thread management, embedded networking (TCP/UDP, IPv4/IPv6), and real-time integration of AI/AIoT capabilities, such as on-device inference and signal processing. Through six hands-on labs and a final project, this course offers practical experience with applications ranging from interactive games to sensor-driven IoT systems, preparing students to design, implement, and debug robust embedded solutions in resource-constrained environments. (Credits: 3)

Course Pre-Requisites / Co-Requisites

⇒ EEL 4744C with a minimum grade of C
⇒ Fluent in C and assembly programming
⇒ Proficiency in Python programming

Course Objectives

The primary objective of this course is to equip students with the theoretical knowledge and practical skills necessary to design, implement, and evaluate embedded systems using real-time operating systems (RTOS). Students will gain a solid understanding of ARM Cortex-M4 processor architecture and apply that knowledge by programming core RTOS components, including thread scheduling, inter-process communication, and synchronization mechanisms such as semaphores and mutual exclusion. Through the hands-on development of a custom RTOS ("**G8RTOS**"), students will demonstrate the ability to design and test reliable, time-sensitive software systems. The course also emphasizes peripheral interfacing using I2C, SPI, and UART protocols, and includes the development of device drivers for common hardware modules such as LEDs, LCDs, joysticks, and wireless networking components. Students will design and implement application-level projects – ranging from interactive games to IoT-enabled sensory systems – that integrate real-time software with hardware functionality. Additionally, students will explore embedded Linux environments and apply foundational concepts in AIoT and TinyML to create AI-enhanced applications involving image and audio processing. The course outcomes align with ABET's focus on applying engineering principles, designing within constraints, functioning on multidisciplinary teams, and preparing students for modern technological challenges in embedded systems and real-time applications.

Materials and Supplies

- TI Tiva C Series LaunchPad and TI SENSOR Booster Pack
- TI BeagleBone Black Board and an integrated on-board camera
- IoT Development Board (with LEDs, LCDs, joystick, networking, and audio functionalities)
- TI Code Composer Studio 11 and Beagle-Board firmware image
- Some relevant libraries and source code (will be provided in class)

Relation to Program Outcomes (ABET):

Outcome	Coverage
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	High
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	Medium
3. An ability to communicate effectively with a range of audiences	
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Low
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Low
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	High
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	High

Recommended Textbooks

1. Real-Time Operating Systems for ARM Cortex-M Microcontrollers (4th Edition) By Jonathan W Valvano. ISBN-13: 978-1466468863, ISBN-10: 1466468866. (PDF available online)

Recommended Online Materials

- Beagle-Board Cookbook. Available online at: https://beagleboard.org/cookbook.
- The Digilent Analog Discovery 2 (DAD) board. Available from the UF Bookstore; also available at DigiKey, Adafruit, and other companies. (*optional, not a must-have)

Grading Policy

Grades are periodically posted online; please check your grades regularly in Canvas. All grades are final one week after posting. More information on the general UF grading policy can be found here: https://catalog.ufl.edu/UGRD/academic-regulations/grades-grading-policies/.

Percent	Grade	Grade Points
92 or More	A	4.00
88.0 - 91.9	A-	3.67
84.0 - 87.9	B+	3.33
81.0 - 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 77.9	C+	2.33
72.0 - 74.9	C	2.00
67.0 - 71.9	C-	1.67
64.0 - 66.9	D+	1.33
60.0 - 63.9	D	1.00
55.0 - 59.9	D-	0.67
Below 55	E	0.00

Evaluation of Grades

Item	Points	% of Final Grade
Hands-on Laboratory (lab1 - lab2)	2 x 7.5	15
Hands-on Laboratory (lab3 - lab5)	3 x 10	30
Hands-on Laboratory (lab6 - lab7)	2 x 7.5	15
Mid-term In-class Exam	1 x 10	10
Milestone Lab Quizzes (q1, q2)	5 + 5	10
Final Project (SF and Final demo)	8 + 12	20
Total		***100***

Required Computer

You **must have** a personal laptop to interface with the devices or sensors to demonstrate your assignment or project progress. We prefer a Linux (Ubuntu) distribution; Windows OS is also fine. Some rare Linux distributions or newer Mac M1/M2 might have some compatibility issues with some sensory interfaces; in such cases, feel free to use virtual OS environments! See the UF student computing requirement at: *https://news.it.ufl.edu/education/student-computing-requirements-for-uf/*

Lab Assignments

[**Lab1**] LED blinking and Console Interfacing (UART) [2 weeks]
Objectives: In this lab, you will blink LEDs on the Tiva Launchpad. You will also output messages using the UART module on the microcontroller and begin using the serial console embedded in the Code Composer Studio (CCS) IDE. The purpose of this lab is to get you used to the IDE, the microcontroller datasheet, and how to build and flash programs into the microcontroller. Part A: Blinking the LEDs on-board Tiva [50 points] Part B: UART initialization, reading outputs on the CCS console [50 points] Bonus points: Toggle between the R/G/B LED colors when a button is pressed. [up to +5 points] Note: To choose which part to build, include that file in the project and exclude the other part by right-clicking on the file in the project explorer in CCS. See the walkthrough: https://youtu.be/k0EVFgi1knY.

[**Lab2**] I2C Communication, Timers, and Sensor Interfacing [2 weeks]
Objectives: In this lab, you will be creating I2C functions to utilize the I2C modules on the Tiva TM4C123GH6PM and using them to interface with sensors on the sensor booster pack. You will output these values and display them on a console (in CCS) using UART communication, and then use timers so that these values and messages are shown at specific rates. See the walkthrough: https://youtu.be/1mDu4DLSRnk. Part A: Interfacing sensor drivers with I2C communication [50 points] Part B: Output sensor data with UART [20 points] Bonus points: Update the accel X value on the LCD screen every 500 ms, and update the optical value on the LCD. You must use timer counters and interrupts for this task. [up to +5 points]

[**Lab3**] G8RTOS Scheduler and Synchronizers [3 weeks]

Objectives: Real-time operating systems (RTOS) are a fundamental part of embedded systems. They guarantee that certain blocks of code will run by using a very robust flow and allocation of execution time to different parts of a program that may not be guaranteed with sequentially-designed code. The main objectives of this lab are to implement multiple threads for dedicated tasks, a scheduler for these threads, and a simple spin-lock semaphore primitive for synchronization. Walkthrough video: https://youtu.be/nEZwr4wGZks.

Part A - Prepare the Basic Structure [10].
Part B - Implementing Threads, Exception Handlers, and Schedulers [40]
Part C - Semaphores & Peripheral Controls [30]
Part D - Add Threads for Sensor Interfacing [15]
Part E - Put it All Together [5]

[**Lab4**] G8RTOS IPC, Dynamic Threads, Priority Scheduling [3 weeks]

Objectives: One of the core features of an RTOS relates to the utilization of threads. This requires an interface between system-level controls, such as the stack pointer, which is provided by select assembly functions. One must consider, however, that a few key things make the threads work as we want them to. The main objectives of this lab are to implement more fine-tuned control over the threads to enable them to communicate with each other, as well as give us hard guarantees of the scheduling order of threads. Walkthrough video: https://youtu.be/yDRkCWjt62c.

Part A: Implementing Blocking, Yielding, Sleeping, and Priority. [25 points]
Part B: Implementing Interprocess Communication [20 points]
Part C: Dynamic Threading, Aperiodic and Periodic Events [25 points]
Part D: Interfacing TFT Display, Joystick [15 points]
Part E: Putting it all together! [15 points]
Bonus points: Change the shape that is rendered to a triangle or a sphere. [up to +5 points]

[**Lab5**] On-device AI/AIoT with RTOS [1 weeks]

Objectives: In this lab, you will learn how to interface a (remote) communication protocol with RTOS. Several systems, including standard video surveillance cameras, remote inspection drones, and doorbell cameras, have very similar applications. For a simplified setup, you will use your laptop to stream a message through the (wired) network to your BeagleBone. Then, we will perform on-device data generation and interface the output on your multimod daughterboard.

Part A: Configuring BeagleBone Black and Communicating with Laptop [60 points]
Part B: Communication Between BeagleBone and Tiva Launchpad [40 points]
Bonus points:

- Set up the Bluetooth communication and send data to Tiva [up to +5 points]
- Run the OpenCV facial detection algorithm through your laptop's webcam [up to +5 points]

[**Lab6**] Real-Time Audio Signal Processing [2 weeks]
Objectives: In this lab, students will integrate Real-Time Operating Systems (RTOS) for Digital Signal Processing (DSP) using provided libraries and procedures to develop an efficient, real-time audio I/O application. Tone detection plays a vital role in digital signal processing, particularly in real-time audio applications such as DTMF. The Goertzel Algorithm is commonly implemented on resource-constrained devices for this purpose. This lab focuses on utilizing this algorithm to analyze the frequency components of audio signals, process them in real-time, and provide visual feedback on the display. This lab will also build on the topics from prior labs to simultaneously output tones via an onboard DAC based on user input. Part A: Audio Input Processing and Tone Detection. [35 points] Part B: Real-Time Audio Output Generation [65 points] Bonus points: Audio Streaming [up to +5 points]

Lab Guidelines

Timeliness and participation

- Do NOT miss any lab! If you cannot make it for appropriate health concerns or unavoidable circumstances, inform us, and we will follow UF guidelines to make arrangements accordingly. See important guidelines at: UF campus brief, health guidelines, UF DSO services.
- **Late lab demo/submission policy**
  - Lab grades are due during the lab hours; TAs may allow minor edits and canvas submissions if they seem only trivial (about ~5%) tasks are left.
  - TAs can allow late submissions/demos with a 30%-50% penalty if major parts are incomplete.
  - No submissions are allowed after the solutions are published.
- Be present at the lab 5-10 minutes earlier, and keep the lab worksheet/manual/soft materials with you.
- **In-lab quizzes**
  - The two milestone quizzes will be in-lab, in the second half of the specific labs.
  - TAs will ask you to implement or demonstrate something relevant to test your hands-on RTOS skills based on the laboratories covered thus far.
- **Final project guidelines**
  - In your last lab, you will need to show a "semi-final demo" of your final project in person; it will be evaluated by the TAs. The final project demo will be a video submission in Canvas; more details will be announced during the class lectures.
  - The final projects are individual; the top five projects will get a +5 bonus and recognition on the course website as the best projects shown in the lecture.
  - We will discuss the details and specific milestones in class

Honesty and integrity

- Do NOT cheat yourself! No place for any form of plagiarism in this course (see UF guidelines).
- Seek help and collaborate with integrity. We are here to help; we will walk you through your code/errors and provide hints and suggestions toward completing your assignments.
- We trust you, and we'll make sure nobody gets an unfair/dishonest advantage

Safety and care

- Do NOT put yourself and others in danger! Take the soldering measures you learned in UP1 laboratories!
- If you are not sure, ask - we are here to help!
- Report anything that needs attention

Course Schedule

Week	Detailed Topics	Reference
1	Course Introduction ● ARM Architecture and OS overview ● CCS overview; contents of lab1 and lab2	Lecture 1 Book Chapter 1 DataSheet Chapter: 1, 2
2-3	Diving Deeper Into ARM Cortex M4 ● Instruction set and memory model ● Board support packages, LED driver interfacing ● Thumb2 instruction sets; unified assembly programming ● Programming and linking between C and assembly ● TIVA C series overview: contents of lab2 and lab3	Lecture 2, 3 Book Chapter: 1, 2.5 DataSheet Chapter: 3, 14, 16
4-8	RTOS Components ● Threads, interrupts, and schedulers ● Process: from OS to RTOS ○ Inter-process communication (IPC) ○ Implementing ICP in your G8RTOS ● Avoiding deadlocks ○ Locks and semaphores ○ Yielding, blocking, sleeping, etc. ● Periodic and dynamic threads ● Contents of lab4 and lab5	Lecture 4, 5 Book Chapter 3 DataSheet Chapter: 10
	Mid-term Exam: 8th week Friday (an in-class written test) **In-lab quiz #1:** 9th week in your regular lab times	
9-10	Advanced RTOS Concepts ● More on dynamic and periodic threads ● Inter-process communication ● Thread priority: FIFO, round-robin ● Aperiodic Event Threads ● Networking Basics: OSI model ● IPv4/IPv6 and TCP/UDP concepts for RTOS ● Hands-on embedded networking concepts ● Contents of lab6 and lab7	Lecture 6, 7 Book Chapter 4, 5 Materials provided in class
11-13	Real-time on-device AI/AIoT Topics ● Embedded AI and on-device ML/vision concepts ● Running AI inference models on Beagle boards ● Integrating RTOS and AIOT ● Audio signal processing overview ● Image/video processing overview (OpenCV tutorial) ● Sample projects and implementation do/donts	Lecture 8, 9 Book Chapter 9, 10 Materials provided in class
14-15	Specific project-based contents; sample projects: - Games: Snake game, Tic-tac-toe, Sudoku, Atari, Tetris, etc. - AIoT: security system, sensor data logger, traffic simulator, etc.	Lecture 10
	In-lab quiz #2: Last week in your regular labs No written final exam; two final project demos instead - **In-person SF project demo:** in your last lab - **Final project demo:** video submission in Canvas by 12/11	

Attendance Policy, Class Expectations, and Make-Up Policy

Attendance in the lectures is not required. However, there will be no make-up for in-class assignments, mid-terms, finals, and homework assignments. The in-class assignments are graded best two out of three, so you can miss at most one without losing points. If you have to miss any classroom activity due to an illness or academic events to attend, please consult the instructor ahead of time for arrangements.

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Follow this link to read the university attendance policies: https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/.

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. Students need to share their accommodation letter with their instructor and discuss their access needs as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback professionally and respectfully is available at https://gatorevals.aa.ufl.edu/students/.

Students will be notified when the evaluation period opens and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor. A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class, or between a student and the faculty or lecturer during a class session. Publication without permission from the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third-party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040, Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge, which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment."

The Honor Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that violate this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Student Privacy

There are federal laws protecting your privacy with regard to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html.

Academic Policies & Resources

To support consistent and accessible communication of university-wide student resources, instructors must include this link to academic policies and campus resources: https://go.ufl.edu/syllabuspolicies. Instructor-specific guidelines for courses must accommodate these policies.

Commitment to a Positive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values.

If you feel like your performance in class is being impacted, please contact your instructor or any of the following:

- Undergraduate Coordinator: Dr Erin Patrick
- HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
- Pam Dickrell, Associate Dean of Student Affairs, 352-392-2177, pld@ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Campus Resources:

Health and Wellness

U Matter, We Care: Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available, including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence, contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS) Student Health Care Center, 392-1161.
University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*: 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://elearning.ufl.edu/.

Career Connections Center: Reitz Union, 392-1601. Career assistance and counseling; https://career.ufl.edu.

Library Support: http://cms.uflib.ufl.edu/ask.

Teaching Center: Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help with brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:*
https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

Online Students Complaints*:* https://distance.ufl.edu/getting-help/;
https://distance.ufl.edu/state-authorization-status/#student-complaint.