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**COURSE SYLLABUS**  
**EEL 4745C: Microprocessor Applications 2**  
Fall 2023

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**INSTRUCTOR**

**Dr. Md Jahidul Islam**

Email: [jahid@ece.ufl.edu](mailto:jahid@ece.ufl.edu)

Office Hours: Wednesdays 5:05 PM - 6:06 PM. @ LAR 339D

**CLASS SCHEDULE**

<u>Lecture</u> : M,W,F   Period 9 LAR 0330   4:00 PM - 4:55 PM	<u>Laboratory</u> : please check ONE.UF for the schedules of your section
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**TEACHING ASSISTANTS**

- **Chen Ruo**. [chenruo@ufl.edu](mailto:chenruo@ufl.edu). OH: **T&R** 12.45-1.45pm; at NEB 281/222.
- **Mehron Talebi**. [mtalebi@ufl.edu](mailto:mtalebi@ufl.edu). OH: **M** 5-6pm; **F** 11am-12pm; at NEB 281/222.

⇒ We will add you to a Teams group where you can communicate forum questions

⇒ Come to OHs and/or please contact through the Teams or Canvas.

**COURSE DESCRIPTION**

Implementation of a Real-Time Operating System (RTOS) on an ARM Cortex M4 processor to develop robust microprocessor functionalities for embedded AI/IoT applications.

**COURSE PREREQUISITES**

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

**COURSE OBJECTIVES**

The primary objective of this course is to understand the basic concepts of RTOS (Real-Time Operating System) and apply that knowledge by programming a microcontroller. Towards this goal, you will learn about the architecture of ARM cortex M4-based processors and program important RTOS components such as implementing threads and thread schedulers as well as handling inter-process communication and synchronization/mutual exclusion via semaphores. Subsequently, you will learn to put things together to develop a working RTOS, *ie*, “G8RTOS” of your own!

You will also learn how to design embedded software driver libraries for peripherals with I2C, SPI, and UART communication paradigms. We will provide an IoT development board with various integrated functionalities with LEDs, LCD, joysticks, and wireless networking components. You will use these on-board functionalities through your G8RTOS to develop various applications; a hands-on project is expected at the end of the course, which is typically either a game (*eg*, snake, tic-tac-toe) or an IoT sensory capability (*eg*, intelligent data logger, line-following robots). To this end, you will learn to interface with a single-board mini computer in an embedded Linux environment to create various AI/IoT applications for image processing, audio processing, and remote/interactive gaming. You will also get exposure to on-device AI and TinyML concepts - to be able to design and develop embedded AI/IoT-based projects in the future.

**MAJOR HARDWARE**

- 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, LCD display, joystick, networking, and audio functionalities)

**SOFTWARE**

- TI Code Composer Studio 11
- 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	Low
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	
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

**TEXTBOOK**

- 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 HARD/SOFT MATERIALS**

- Beagle-Board Cookbook. Available online at: <https://beagleboard.org/cookbook>.
- The Diligent Analog Discovery 2 (DAD) board. Available from the UF Bookstore; also available at DigiKey, Adafruit, and other companies. *If you already have one from previous uP1/DSP courses - that will do! (\*not a must have)*

**LAPTOP & OS**

You must have a personal laptop to interface with the devices and show your assignment/project progress. Our lectures/materials are based on Windows; however, Mac/Linux should also work with the standard driver-level adjustments. *Some rare Linux distributions or newer Mac-M1 chips might have some compatibility issues; in such cases, feel free to use virtual OS environments!*

**COURSE GRADE BREAKDOWN**

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
<b>Total</b>		<b>100</b>

**GRADING POLICY**

Grades are periodically posted online; please check your grades regularly. All grades are final after one week since 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

**LABORATORY SCHEDULE**

Lab	Topic	Lab Timeline
1	Introduction and Setup <ul style="list-style-type: none"> <li>Part A: Blinking the LEDs on-board the Tiva Launchpad</li> <li>Part B: UART initialization, reading outputs on the CCS console</li> </ul>	Week 1
2	Basic Interfacing, Linking, and Communication <ul style="list-style-type: none"> <li>Part A: Interfacing sensor drivers with I2C communication</li> <li>Part B: Output sensor data with UART</li> <li>Part C: Sampling sensors at different rates with Timers Interrupts</li> </ul>	Week 2-3 <a href="#">Demo 2A Due: Week 3</a> <a href="#">Demo B/C Due: Week 4</a>
3	G8RTOS Scheduler and Synchronizers <ul style="list-style-type: none"> <li>Part A: OS Structures</li> <li>Part B: Threads, exception handlers, and schedulers</li> <li>Part C: Semaphores &amp; peripheral controls</li> <li>Part D: Threads for Sensor Interfacing</li> <li>Part E: Putting it all together with LED and sensor modules</li> </ul>	Week 4-6 <a href="#">Demo A Due: Week 4</a> <a href="#">Demo B/C Due: Week 5</a> <a href="#">Demo D/E Due: Week 6</a>
4	G8RTOS Periodic Threads and Queueing <ul style="list-style-type: none"> <li>Part A: Implementing blocking, yielding, and sleeping</li> <li>Part B: Priority scheduling, periodic and background threads</li> <li>Part C: Dynamic and aperiodic threads</li> <li>Part D: Interprocess Communication</li> <li>Part E: Putting it all together for LCD and audio functionalities</li> </ul>	Week 7-9 <a href="#">Demo A/B Due: Week 7</a> <a href="#">Demo C/D Due: Week 8</a> <a href="#">Demo E Due: Week 9</a>
<b>Mid-term Week</b>	The mid-term exam will be in-class (the only paper-based exam) Lab quizzes will be in regular laboratory schedules	<b>In-lab quiz #1: Week 9</b>
5	Bluetooth & Networking basics with RTOS <ul style="list-style-type: none"> <li>Part A: Interfacing with Bluetooth transceiver</li> <li>Part B: RTOS integration</li> </ul>	Week 10-11 <a href="#">Demo Due: Week 11</a>
6	Beaglebone Setup <ul style="list-style-type: none"> <li>Part A: Interfacing and communication with a BeagleBoard</li> <li>Part B: Interfacing between Tiva and the BeagleBoard</li> </ul>	Week 12 <a href="#">Demo Due: Week 12</a>
7	AIoT with RTOS <ul style="list-style-type: none"> <li>Part A: Getting and processing camera data (OpenCV)</li> <li>Part B: On-device AI with OpenCV</li> </ul>	Week 13-14 <b>In-lab Quiz #2: Week 13</b> <a href="#">Demo Due: Week 14</a>
<b>Final Project</b>	<b>Individual work:</b> a game or sensory feature (details will be discussed in class. [in-person demo: in your last lab; final demo: video submission])	<b>SF Demo: Week 15</b> <a href="#">Final Demo: 12/15 (canvas)</a>

## LABORATORY GUIDELINES

### Timeliness and participation

- Do NOT miss any lab! If you cannot make it for appropriate health concerns or absolutely 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, keep the lab worksheet/manual/soft materials with you.
- In-lab quizzes
  - The two milestone quizzes will be in-lab: 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; top five projects will get a +5 bonus and recognition in the course website as the best projects in Fall-2023.
  - 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 unfair/dishonest advantage

### Safety and care

- Do NOT put yourself and others in danger! Take soldering measures you learned in uP1 laboratories!
- If you are not sure, ask - we are here to help!
- Report anything that needs attention

## ATTENDANCE, EXCEPTIONS, & MAKE-UP POLICY

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; visit this link for the details: <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

## COURSE MATERIALS BREAKDOWN

Week	Detailed Topics	Reference
1	Course Introduction <ul style="list-style-type: none"> <li>ARM Architecture and OS overview</li> <li>CCS overview; contents of lab1 and lab2</li> </ul>	<a href="#">Lecture 1</a> <a href="#">Book Chapter 1</a> <a href="#">DataSheet Chapter: 1, 2</a>
2-3	Diving Deeper Into ARM Cortex M4 <ul style="list-style-type: none"> <li>Instruction set and memory model</li> <li>Board support packages; LED driver interfacing</li> <li>Thumb2 instruction sets; unified assembly programming</li> <li>Programming and linking between C and assembly</li> <li>TIVA C series overview; contents of lab2 and lab3</li> </ul>	<a href="#">Lecture 2, 3</a> <a href="#">Book Chapter: 1, 2.5</a> <a href="#">DataSheet Chapter: 3, 14, 16</a>
4-8	RTOS Components <ul style="list-style-type: none"> <li>Threads, interrupts, and schedulers</li> <li>Process: from OS to RTOS               <ul style="list-style-type: none"> <li>Inter-process communication (IPC)</li> <li>Implementing ICP in your G8RTOS</li> </ul> </li> <li>Avoiding deadlocks               <ul style="list-style-type: none"> <li>Locks and semaphores</li> <li>Yielding, blocking, sleeping, etc.</li> </ul> </li> <li>Periodic and dynamic threads</li> <li>Contents of lab4 and lab5</li> </ul>	<a href="#">Lecture 4, 5</a> <a href="#">Book Chapter 3</a> <a href="#">DataSheet Chapter: 10</a>
<b>Mid-term Exam: 9th week Friday (an in-class written test)</b> <b>In-lab quiz #1: 9th week in your regular labs</b>		
9-10	Advanced RTOS Concepts <ul style="list-style-type: none"> <li>More on dynamic and periodic threads</li> <li>Inter-process communication</li> <li>Thread priority: FIFO, round-robin</li> <li>Aperiodic Event Threads</li> <li>Networking Basics: OSI model</li> <li>IPv4/IPv6 and TCP/UDP concepts for RTOS</li> <li>Hands-on embedded networking concepts</li> <li>Contents of lab6 and lab7</li> </ul>	<a href="#">Lecture 6, 7</a> <a href="#">Book Chapter 4, 5</a> Materials provided in class
11-13	Real-time on-device AI/AIoT Topics <ul style="list-style-type: none"> <li>Embedded AI and on-device ML/vision concepts</li> <li>Running AI inference models on Beagle boards</li> <li>Integrating RTOS and AIOT</li> <li>Audio signal processing overview</li> <li>Image/video processing overview (OpenCV tutorial)</li> <li>Sample projects and implementation do/donts</li> </ul>	<a href="#">Lecture 8, 9</a> <a href="#">Book Chapter 9, 10</a> Materials provided in class
14-15	Specific project-based contents; sample projects: <ul style="list-style-type: none"> <li>Games: Snake game, Tic-tac-toe, Sudoku, Atari, Tetris, etc.</li> <li>AIoT: security system, sensory data logger, traffic simulator, etc.</li> </ul>	<a href="#">Lecture 10</a>
<b>In-lab quiz #2: 13th week in your regular labs</b> No written final exam; two final project demos instead <ul style="list-style-type: none"> <li><b>In-person SF project demo:</b> in your last lab (15th week)</li> <li><b>Final project demo:</b> video submission in canvas by 12/15</li> </ul>		

## **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 in a professional and respectful manner 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 Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Moreover, the summaries of course evaluation results will be available to students at this link: <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 of 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 & 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: “In my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code listed in this link (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

## **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.

## STUDENT PRIVACY

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

## COMMITMENT TO A SAFE & INCLUSIVE LEARNING ENVIRONMENT

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

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

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

## CAMPUS RESOURCES

**Covid-19 Protocols:** [UF campus brief](#), [UF health guidelines](#)

### 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](mailto: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](mailto: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/>.  
**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).  
<https://lss.at.ufl.edu/help.shtml>.

**Career Connections Center**, Reitz Union, 392-1601. <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. <https://teachingcenter.ufl.edu/>.

**Writing Studio**, 302 Tigert Hall, 846-1138. <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>.

**On-Line Students Complaints:** <http://www.distance.ufl.edu/student-complaint-process>.