

## Real-time DSP Applications

EEE 4511C Sections 20572, 20574, 20575, 29084

**Class Periods:** MWF Period 5, 11:45am-12:35pm

**Location:** LAR 330

**Academic Term:** Spring 2024

### **Instructor:**

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### **Teaching Assistant/Peer Mentor/Supervised Teaching Student:**

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### **Course Description**

Real world digital signal processing (DSP) tasks are presented and solved in a lab environment that utilizes a modern radio-frequency system-on-chip (RFSoc) development board & a sophisticated code development tools/hardware emulation.

### **Course Pre-Requisites / Co-Requisites**

EEL 3135 (basic signals & systems knowledge) and C/C++ programming experience

### **Course Objectives**

This course introduces the practices of high-speed (up to several G samples per second) implementation of DSP objects, such as FIR/IIR filters and FFT, using a modern heterogeneous system-on-chip (SoC) hardware platform and development tools. Upon completion of this course, students should be able to:

- understand the basic development process for a modern SoC system,
- use the Vitis Unified Software Platform as a tool to develop embedded applications on the RFSoc 4x2 board,
- understand different implementation structures of FIR and IIR filters and FFT, and the effects of finite-precision implementation, and
- use high-level synthesis (HLS) to develop real-time high-speed filter and FFT implementation.

### **Materials and Supply Fees**

Remote access to the [RealDigital RFSoc 4x2 boards](#) will be provided.

### **Relation to Program Outcomes (ABET):**

The table below is an example. Please consult with your department's ABET coordinator when filling this out.

Outcome	Coverage*
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	Medium
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	

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	
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	
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	Medium

\*Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

### **Required Textbooks and Software**

No required textbook. Course notes will be provided.

Required Software:

- [AMD Vitis Core Development Kit 2023.2.1](#)
  - A docker image, including all required Vitis-Vivado components, board files, and Vitis platforms, will be provided.
- MATLAB & Signal Processing Toolbox (for filter design)

Vitis Unified Software Platform Documentation:

- [Application Acceleration Development \(UG1393\)](#)
- [Vitis High-Level Synthesis User Guide \(UG1399\)](#)
- [Embedded Software Development \(UG1400\)](#)

### **Recommended Materials**

- Digital Signal Processing: Principles, Algorithms, and Applications  
John G. Proakis and Dimitris G. Manolakis  
2022, 5<sup>th</sup> edition  
ISBN: 0-13-734824-X  
Chapters 8 & 9
- Discrete-Time Signal Processing  
Alan V. Oppenheim and Ronald W. Schaffer  
2010, 3<sup>rd</sup> edition  
ISBN: 0-13-198842-5  
Chapter 6

### **Course Schedule**

#### Part I: RFSoc Hardware and Development Tools

Week 1: Course overview, RFSoc hardware platform, and Vitis development toolchain  
**Lab 1: Vitis installation, embedded development example, and GitHub submission**

- Week 2: Introduction to heterogenous/embedded system development and Vitis application acceleration development flow  
 Lab 1: Vitis installation, embedded development example, and GitHub submission
- Week 3: Introduction to high-level synthesis (HLS) and Vitis HLS development flow  
 Lab 2: Simple HLS kernel, test bench, C simulation, synthesis, and C/RTL co-simulation
- Week 4: HLS design basics: Producer-consumer model, dataflow graph, FIFO and PIPO buffers, control- and data-driven tasks, task-level parallelism and pipelining  
 Lab 3: Task-level parallelism, FIFO and PIPO, data- and control-driven task
- Week 5: HLS programming: Loops, arrays, functions, fixed-/floating-point and arbitrary-precision data types  
 Lab 4: Loops, arrays, functions, and data types
- Week 6: HLS programming: Interface to HLS kernel, load-compute-store coding pattern, global memory access  
 Lab 5: Interface to HLS kernel and LCS code pattern
- Week 7: Process system (PS) programming: OpenCL primer, interface to HLS kernels, simple parallelization techniques  
 Lab 6: Vitis system project and OpenCL host code  
 Exam 1

### Part II: Real-time DSP Implementation

- Week 8: Signal flow graph representation, FIR filter implementation: direct-, transposed-, and cascade-form  
 Lab 7: FIR filters
- Week 9: IIR filter implementation: direct-, transposed-, cascade-, and parallel-form  
 Lab 8: IIR filters
- Week 10: Lattice filters and systolic implementation  
 Lab 9: Lattice filters
- Week 11: Fixed- vs. floating-point implementation, coefficient quantization, roundoff noise, overflow. Limit-cycle oscillation  
 Lab 10: Effects of quantization in filter implementation
- Week 12: FFT implementations and quantization effects  
 Lab 11: FFT implementation  
 Exam 2

### Part III: System Integration

- Week 13: Sampling theorem, interfacing with ADCs on RFSoc 4x2 board  
 Lab 12: Vitis platform development and ADC interface
- Week 14: Real-time FM spectrum sensor  
 Lab 13: Real-time FM spectrum sensor
- Week 15: Real-time HD radio signal classifier (if time allows)  
 Lab 14: Real-time HD radio signal classifier (if time allows)

### **Attendance Policy, Class Expectations, and Make-Up Policy**

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Click here to read the university attendance policies:

<https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

### **Evaluation of Grades**

<b>Assignment</b>	<b>Total Points</b>	<b>Percentage of Final Grade</b>
Labs (~13)	100 each	70%
Exam 1	100	15%
Exam 2	100	15%
Total		100%

### **Grading Policy**

The following is given as an example only. The grading scheme may be adjusted according to average class performance.

<b>Percent</b>	<b>Grade</b>	<b>Grade Points</b>
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

### **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/>. 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 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 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 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 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 are in violation of 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.

### ***Commitment to a Safe and Inclusive 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, including the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of race, creed, color, religion, age, disability, sex, sexual orientation, gender identity and expression, marital status, national origin, political opinions or affiliations, genetic information, and veteran status.

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
- HWC OE Human Resources, 352-392-0904, [student-support-hr@eng.ufl.edu](mailto:student-support-hr@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshiyazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.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.

### ***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>

### ***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](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/>.

#### Academic Resources

**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. Career assistance and counseling; <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. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

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

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