ECE 1175: Embedded Systems Design

Fall 2025 Course Syllabus

- **Lecture:** Wednesday 13:50 – 16:25 at N208
- **Instructor:** Guanqiang "Tim" Zhou <guanqiang.zhou@scupi.cn>
- **Office Hours:** Wednesday & Thursday 10:30 – 13:30 at N512 (or by appointment)
- **Teaching Assistant:** Jiahao Li <2023141520010@stu.scu.edu.cn>
- **Textbook:** *Introduction to Embedded Systems: A Cyber-Physical Systems Approach*, 2nd Edition, by Edward A. Lee and Sanjit A. Seshia, MIT Press. Free download available at http://leeseshia.org

Course Description

Embedded systems play an integral role in many aspects of our lives. These networked computing systems embedded in the physical world drive technologies such as automotive control systems, aerospace applications, medical devices (from large-scale proton therapy machines to small implantable devices), process control, and energy production and management.

Despite advances in hardware and software, embedded systems as a principled discipline is still relatively new. This development provides an opportunity to adopt a more rigorous approach to the design of these systems—reducing cost, increasing reliability, and enabling innovation by applying formal principles.

This course is about the *intellectual principles* behind embedded system design, with a focus on **model-based design**. We will study three general themes:

- **Modeling**: formally expressing what a system does,
- **Design**: developing artifacts to achieve particular system goals,
- **Analysis**: specifying and checking important system properties.

This is a **multi-disciplinary** course. It draws upon and integrates topics such as differential equations, signals and systems, control theory, automata and language theory, discrete mathematics, concurrency, computer architecture, embedded platforms, software, sensors and actuators, networking, and dependability. Students will explore modeling techniques, multitasking, quantitative systems analysis, and formal specification and verification.

While no hardware lab is required this semester, students will gain experience in end-to-end design issues through problem sets, simulations, and case studies, using state-of-the-art tools for model-based design where possible. Familiarity with differential equations, logic, and set theory is required; some background in C programming or modeling tools (MATLAB/Simulink, LabVIEW) is helpful but not required.

Course Objectives

1. Introduce the theoretical foundations of embedded and cyber-physical systems.
2. Provide a unified framework for modeling continuous, discrete, and hybrid dynamics.
3. Explore architectures of embedded processors, memory, I/O, and multitasking.
4. Study principles of real-time scheduling, concurrency, and resource management.
5. Develop skills in system analysis: invariants, verification, timing analysis, and security.
6. Prepare students to critically assess real-world embedded system designs using model-based methods.

Learning Outcomes

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

- Construct models of embedded systems using state machines, hybrid systems, and concurrency formalisms.
- Apply signals-and-systems concepts (sampling, aliasing, quantization) to embedded design problems.
- Evaluate scheduling algorithms (RMS, EDF) and analyze task sets for feasibility.

- Explain how sensors, actuators, processors, and memory architectures affect system dynamics.
- Use formal methods (invariants, temporal logic, reachability) to reason about correctness.
- Analyze dependability, timing, and security challenges in embedded system design.

Tentative Lecture Schedule

- Week 1: Introduction to Embedded Systems (Ch. 1)
- Week 2: Continuous Dynamics (Ch. 2)
- Week 3: Discrete Dynamics & Finite State Machines (Ch. 3)
- Week 4: Hybrid Systems (Ch. 4)
- Week 5: Composition of State Machines (Ch. 5)
- Week 6: Concurrent Models of Computation (Ch. 6)
- Week 7: Sensors and Actuators (Ch. 7)
- Week 8: Midterm Exam
- Week 9: Embedded Processors (Ch. 8)
- Week 10: Memory Architectures (Ch. 9)
- Week 11: Input and Output (Ch. 10)
- Week 12: Multitasking (Ch. 11)
- Week 13: Scheduling (Ch. 12)
- Week 14: Analysis I — Invariants, Temporal Logic, Model Checking (Chs. 13–15)
- Week 15: Analysis II — Quantitative Analysis, Security and Privacy (Chs. 16–17)
- Week 16: Case Studies & Course Review
- Week 17: Final Exam

Grading

- Attendance and Participation: 10%
- Homework Assignments: 20%
- Midterm Exam: 30%
- Final Exam: 40%

Code of Academic Conduct

Students are expected to adhere to the highest standards of academic integrity.

- **Collaboration**: Discussion of concepts and general approaches is encouraged, but all submitted work must be your own.
- **Plagiarism**: Copying from peers, prior semesters, online sources, or AI-generated content without attribution is strictly prohibited.
- **Exams**: Closed-book unless otherwise specified. Use of unauthorized materials will result in disciplinary action.
- **Citations**: Any external sources used in assignments or presentations must be properly cited.
- **Consequences**: Violations will be handled in accordance with university policy and may result in penalties ranging from assignment failure to course failure or referral to the academic integrity office.