1. **Number and title of course:** EE/CS-C 149, Introduction to Embedded Systems

2. **Catalog description:** (4 units) This course introduces students to the basics of models, analysis tools, and control for embedded systems operating in real time. Students learn how to combine physical processes with computation. Topics include models of computation, control, analysis and verification, interfacing with the physical world, mapping to platforms, and distributed embedded systems. The course has a strong laboratory component, with emphasis on a semester-long sequence of projects.

3. **Prerequisites:** EE 20n, CS 61C, CS 70 or Math 55

4. **Course objectives:** This course is intended to introduce students to the design and analysis of computational systems that interact with physical processes. Applications of such systems include medical devices and systems, consumer electronics, toys and games, assisted living, traffic control and safety, automotive systems, process control, energy management and conservation, environmental control, aircraft control systems, communications systems, instrumentation, critical infrastructure control (e.g., electric power, water resources, and communications systems), robotics and distributed robotics (telepresence, telemedicine), defense systems, manufacturing, and smart structures.

A major theme of this course will be on the interplay of practical design with formal models of systems, including both software components and physical dynamics. A major emphasis will be on building high-confidence systems with real-time and concurrent behaviors.

The course has a strong laboratory component, with emphasis on a semester-long sequence of labs leading into a final course project.

5. **Topics covered:**
   - Introduction to embedded systems; Cyber-physical systems
   - Model-based design
   - Sensors and actuators
   - Interfacing to sensors and actuators
   - Actors, Dataflow
   - Modeling modal behavior – Part I
   - Modeling modal behavior – Part II
   - Concurrency 1: Interrupts
   - Hybrid systems – Part I: Modeling
   - Hybrid systems – Part II: Basic control design
   - Simulation strategies
   - Concurrency 2: Threads
   - Operating systems, Microkernels, Scheduling
   - Scheduling anomalies
   - Execution time analysis
   - Specification, Temporal logic
   - Reachability analysis and verification
   - Controller synthesis for finite-state systems
   - Controller synthesis for hybrid systems
   - Distributed embedded systems in an automotive context (CAN and FlexRay)
   - Concurrency Models I
   - Concurrency Models II
   - Security for embedded systems
• Real-time networking

6. **Contribution of course meeting the professional component:** (To be determined by the Undergraduate Study Committee)

7. **Relationship of course to program outcomes:** In this course, students learn to design, analyze, and implement systems that integrate computation with the physical world. It strengthens students’ capacity for abstract thinking and theoretical work, by placing an emphasis on formal modeling and analysis, and also strengthens both their hardware and their software implementation skills by using a sequence of labs and projects. Students also gain valuable experience on working in teams to achieve self-defined objectives in a final project spanning several weeks. Students achieve an understanding of fundamental algorithms, formalisms, and tools to design dependable and secure cyber-physical systems with characteristics that include heterogeneity, concurrency, networking, and real-time behavior.

8. **Prepared by:** Sanjit A. Seshia (4/2009)