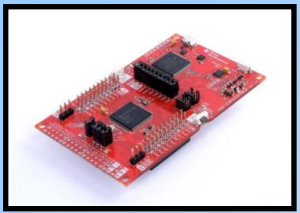

# Embedded System Design

## ECEN 5613 – Fall 2018

**Monday Evenings**, 6:00pm–8:30pm

Instructor: Prof. Linden McClure, Dept. of Electrical, Computer, and Energy Engineering
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Course Web Site: http://ecee.colorado.edu/~mcclurel/index.html

See the Embedded Systems Engineering web site for more information:
https://www.colorado.edu/ecee/graduate-program/degrees/embedded-systems

## Course Description

In this class, the fundamentals of embedded system hardware and firmware design will be explored, including:

- Processor selection
- Power delivery, decoupling
- Clocks and resets
- Assembly programming
- Embedded C programming
- Incremental development (HW, SW)
- Test equipment / instrumentation (oscopes, multimeters, logic analyzers)
- Debugging techniques
- Data sheets
- Bus cycles, transaction types, timing diagrams, timing analysis
- Memory maps, chip select logic
- Serial interfaces (RS-232, $I^2C$, SPI)
- I/O port pin driver circuits
- In-circuit programming
- Device drivers
- Interrupts and ISR's
- Memory mapped I/O
- Data conversion (DAC's, ADC's)
- Design reviews
- Design trade-offs
- Entrepreneurship
- Passive components

Topics such as embedded processor selection, glue logic, circuit design, circuit layout, circuit debugging, development tools, firmware architecture, firmware design, and firmware debugging will be discussed. The architecture and instruction sets of at least two microcontrollers will be studied, a microcontroller board with peripherals will be built and debugged by each student, and an ARM-based development board will be used for hardware interfacing and firmware development. Students will develop embedded software in C and assembly. The course will culminate with a significant final project which will extend the base microcontroller board completed earlier in the course. Learning may be supplemented with periodic guest lectures by embedded systems engineers from industry. **This course serves as an excellent preparatory course for the other courses in the Embedded Systems Engineering program, and provides students with key skills that are important for job interviews.** This core course also counts for the Embedded Systems Certificate. See the course web site for more information.

### Required Background

Knowledge of and skills in microprocessor architecture and assembly language, microprocessor peripherals, digital design, and the C programming language are prerequisites for this course. Although not listed as formal prerequisites, circuits/electronics and computer organization are highly recommended. An understanding of compilers, assemblers, linkers, operating systems, analog design, diodes, and transistors will be useful.

### Course Context

Embedded systems are involved in almost every facet of modern life. Smart phones, tablets, MP3 players, virtual reality systems, energy conversion systems, medical equipment, answering machines, microwave ovens, televisions, VCRs/DVRs, CD/DVD players, video game consoles, GPS devices, network routers, fax machines, cameras, music synthesizers, planes, drones/UAVs, spacecraft, boats, and cars all contain embedded processors. Late model cars may contain as many as 65 embedded microprocessors, controlling such tasks as antilock braking, climate control, engine control, entertainment system control, collision avoidance, airbag deployment, etc. The Boeing 777 aircraft contains over 1,200 processors and more than 4 million lines of software! Logic analyzers and digital storage oscilloscopes utilize embedded processors to support real-time operation. Even PCs, which are designed around powerful CPUs, contain embedded systems. Storage drives (hard disk, solid state, CD-RW, DVD-RW, Blu-ray), and external peripherals such as printers, scanners, and other SATA, SAS, USB, or IEEE 1394 devices all contain embedded processors. In years when microprocessor manufacturers sold on the order of 100 million processors for use as computer CPUs, they sold more than **3 billion** embedded processors, primarily consisting of 32-bit, 16-bit, 8-bit, and 4-bit devices. The tremendous number of applications for embedded computing has given rise to high demand for engineers with experience in designing and implementing embedded systems. This course will give students hands-on experience and opportunities for experimentation and careers in this exciting field.