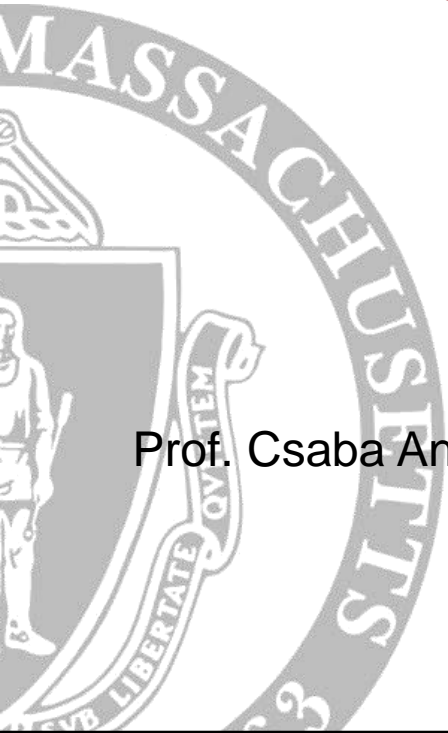


# Embedded System Lab Course Comparison

what other universities do

Prof. Csaba Andras Moritz, and students Sachin Bhat, Omid Meh and Sam Baldwin

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# Summary Findings

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- Variety of approaches can be seen
  - From MCUs to FPGA boards
  - Most labs disjoint vs. building on each other for a larger system
  - Software design as well as Verilog projects
- Existing ECE354 UMass Amherst is on par with other top Universities when it comes to the course materials and choice of FPGA education boards
  - Students in redesign team ranked UMass Amherst approach highly
  - We have a chance to further improve and create a nice offering (likely better than others/most)
- Cornell University also uses Altera DE2 board for a similar course and lately transitioning to DE1 SoC (our recommendation also – see our related PPT)
  - DE1 SoC board can be used in wide array of course projects

## Boards & features used in courses

<b>University</b>	<b>Course</b>	<b>Board</b>
MIT	6.190	Spartan-6 LX45
Stanford	CS241/EE281	ARM Cortex-M0/M4, 8-bit AVR
UC Berkeley	CS150	XUPV5 LX110T
CMU	ECE348	Freescale MC9S12C128
Univ. of Illinois	ECE385	Altera DE2
UMich	EECS373	SmartFusion FPGA, Cortex-M0/M4
GA Tech	ECE2035	Mbed NXP LPC1768 (Cortex-M3), Intel Atom
Caltech	EECS51/52	X86 assembly
WPI	ECE3829	Artix-7

## Boards & features used in courses (cont.)

<b>University</b>	<b>Course</b>	<b>Board</b>
Cornell	ECE5760	Altera DE2/DE2-115 w/ NIOS
GA TECH	ECE2031	Altera DE2/DE2-70, UP3

# UC Berkeley CS150

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- Uses Xilinx XUPV5-LX110T (Virtex-5)
- Groups of 2
- 5 structured labs for one half of the semester
- One half-semester long group project of medium complexity for remainder
- Creation of basic RTL circuits (counters, encoders)
- Mapping of RTL circuits to FPGA
- Learn Chipscope
- Run Microblaze on FPGA, compile C for it
- Build Finite-Impulse Response filter in Verilog
- Connect to button/switch and LED peripherals
- Power management

# UMich EECS373

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- Uses SmartFusion FPGA & ARM Cortex-M3
- Logic analyzer
- Interrupts, timers
- Memory mapped IO
- SPI/I<sup>2</sup>C/UART
- Design of a custom low power wireless protocol
- Students program FPGA in Verilog to design interrupt controllers and link peripherals
- Write embedded C for ARM to drive peripherals

# CMU 348

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- Uses MC9S12C MCU
- Students form 2-4 person teams
- Weekly labs requiring ~12 hours/student a week
- CPU12 embedded C
- CPU12 asm, memory structure, mixed C/asm to drive peripherals in same project
- Focus on optimization
- Memory mapped IO to digital peripherals (SPI), timers
- Co-operative and pre-emptive context switching
- Analog IO (PWM)

# Stanford EE281

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- Uses Atmel AT90S8515 microcontroller
- Four single-person labs throughout semester
- AVR Studio
- Basic integration of digital peripherals like LEDs/LCDs
- Combined assembly and C
- Students build ASCII to Morse converter
- LCD desk clock



# Stanford CS241

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- Uses ARM Cortex-M0 (on nRF51822), Beaglebone & Raspberry Pi
- Students work alone or in small groups on a semester-long project
- Class is in embedded C with inline asm
- Includes digital & analog peripherals
- Covers interrupts and concurrency
- Power management (low power operations)
- Wireless peripherals
- Sensors
- Non-volatile storage

# Cornell ECE5760

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- Uses DE2/DE2-115 w/ NIOSII
- 5 consecutive lab assignments per semester
- Focus on mathematical computing
  - Hardware ODE solver
  - Multiprocessor PDE real-time synthesis of nonlinear drum
- Cornell student conducted a study of the DE1-SOC to assess fitness for replacing DE2
  - Concluded that ARM core added learning opportunities (particularly hardware/software tradeoffs), at the expense of higher complexity and compile time
  - Mid transition to DE1 now

# GATech ECE2031

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- Uses DE2/DE2-70
- UP3/2/1 as optional boards student can purchase
- Follows lab structure like Electronics I: academic prelab, simultaneous whole-class lab times, and graded lab reports
- 11 individual labs per semester
- Uses a selection of secondary chips, differing per assignment (LS, HC/HCT)
- Mid transition to DE1

# Sources

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- 1) <http://web.mit.edu/~bdaya/www/RPES/Board/Board.htm>
- 2) <http://web.stanford.edu/class/ee281/materials.html>
- 3) <http://web.stanford.edu/class/cs241/>
- 4) <http://www-inst.eecs.berkeley.edu/%7Eecs150/fa13/lab0/lab0.pdf>
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- 6) <http://www.ece.cmu.edu/~ece348/index.html>
- 7) <https://web.archive.org/web/20120308133531/http://courses.engr.illinois.edu/ece385>
- 8) <http://eecs.umich.edu/eecs/academics/courses/eecs-373.html>
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- 13) <http://people.ece.cornell.edu/land/courses/ece5760/>