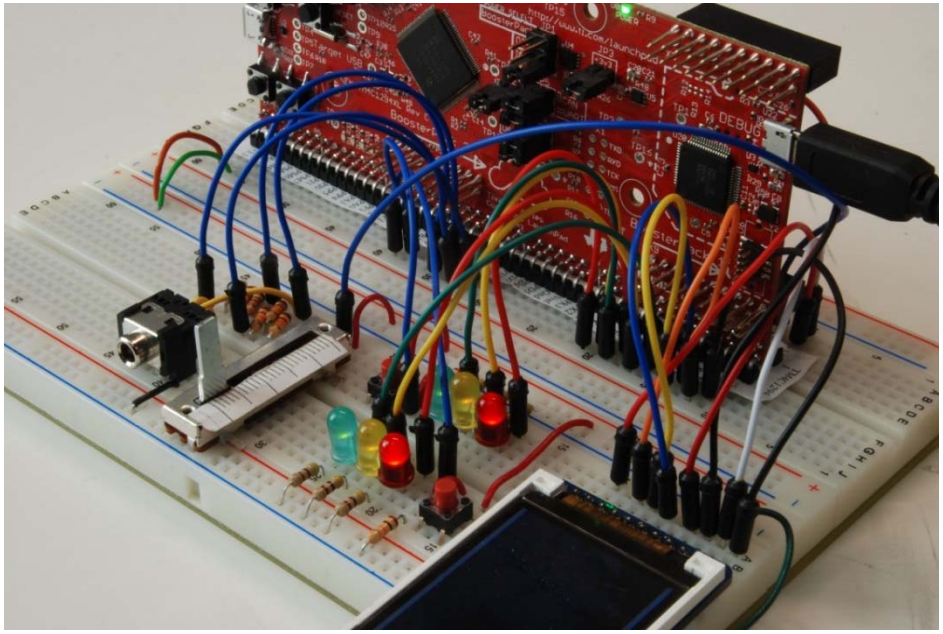
Embedded Systems Laboratory

- Using ARM Cortex M4
- From the Basics to Applications
- MOOC experiences



Why M4?

- Market share
- Complexity
- Parallelism
- Verification

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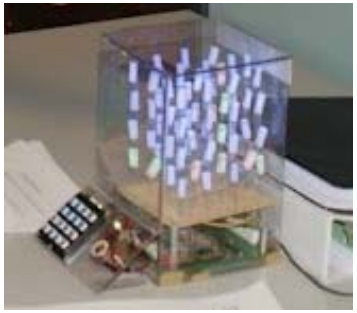
Outline

1. **Objectives**
2. **Approach → 5 Takeaways**
3. **Boards, Books and Labs**
4. **Successes → Competitions**
5. **Conclusions**

What do students need forever?



Engineers make two things:

- Systems
- Interfaces between systems

1. Objectives

- Outcomes, Measureables
  - Career opportunities
  - Economic growth
  - Student feedback
- Educational effectiveness
  - Improved performance
  - Reduced resources
- Educational team

2. Takeaway: Bottom up (what?)

- Bottom up: From simple to complex
  - Transistors→Gates→Computer→Systems
  - Assembly → C → Java/C++ → LabVIEW
- Abstraction
  - Understand → Put it in a box → Use the box
- Systems
  - Take two systems→ Connect → New system+

2. Takeaway: Lab-centered

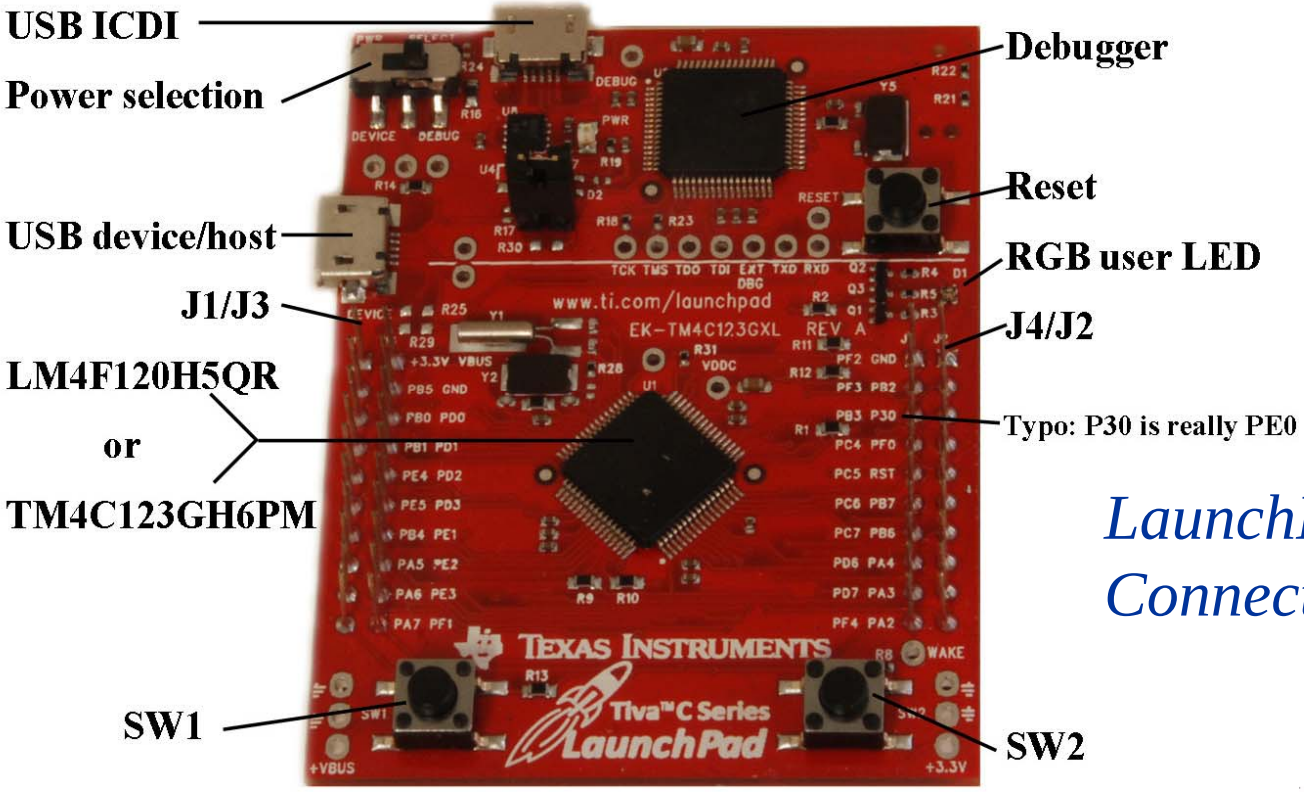
Students learn by doing

- **Equipment must work**
- **Assignments must be clear**
- **Tasks support learning objectives**
- **Professors must do labs**

Students learn by teaching

2. Takeaway: Empower Students

- **Students should have their own board**



LaunchPad $13
Connected LP $20

2. Takeaway: Empower Students

Students need to learn outside of lab

- **Students should have their own DVM**
- **Show labs to friends and parents**
- **Encourage them to work beyond lab**
  - **Find sources of free parts**
  - **Give simple stuff away**
- **Mentor their careers**
  - **Job versus grad school**
  - **Online presence**

2. Takeaway: Flexibility

Students learn at different speeds and in different ways

- **Some need structure**
  - **Demonstrate working labs**
- **Some thrive on open ended design**
  - **Let students negotiate deliverables**
- **Allow for extra credit**
- **Create an open-ended design lab**

2. Takeaway: Team-approach

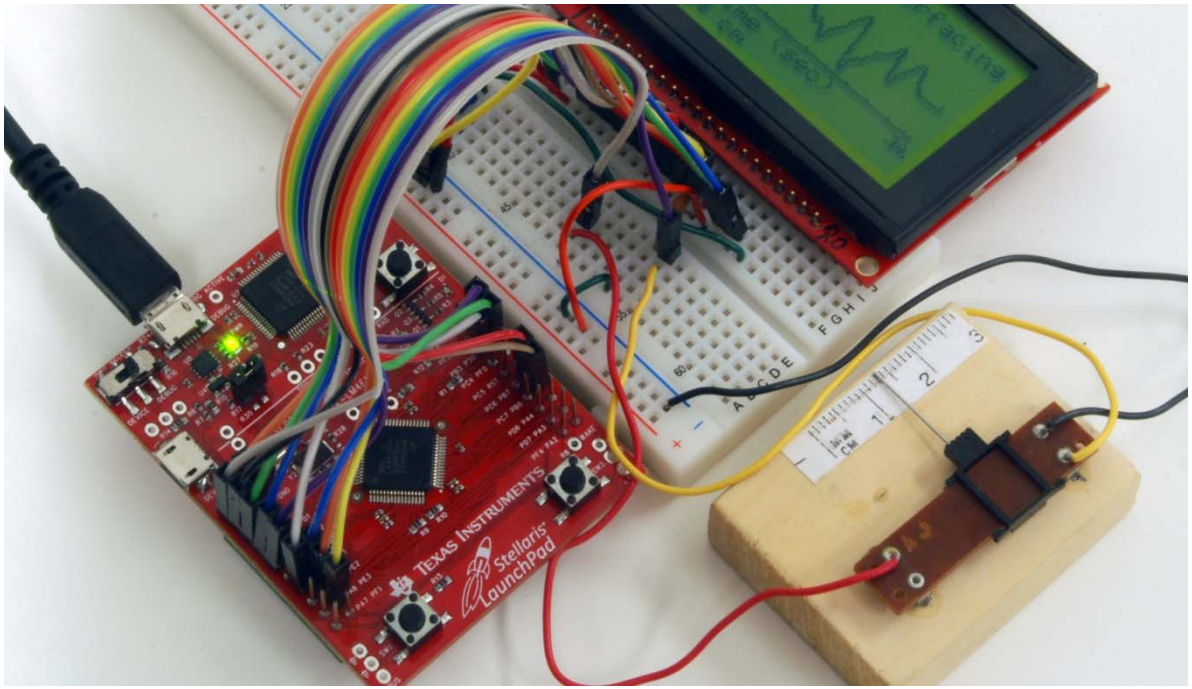
It takes a village to educate

- **Empower the TAs**
  - **Invite them into the decision circle**
- **Empower the staff**
  - **Invite them into the decision circle**
- **Make excuses to show off projects**
  - **Chairman, Dean, Newspaper**
  - **Make promotion about the students**

3. Boards, Books and Labs

Tiva LaunchPad TM4C123

$13



- 43 I/O pins
- 32k RAM
- 256k EEPROM
- 80 MHz Cortex-M4
- serial, SPI, ADC, CAN
- timer, PWM, DMA
- interrupt controller
- JTAG debugger
- serial through USB
- floating point

EK-TM4C1294XL, 90 I/O pins, 256k RAM, 1M ROM, 120 MHz, Ethernet

$20

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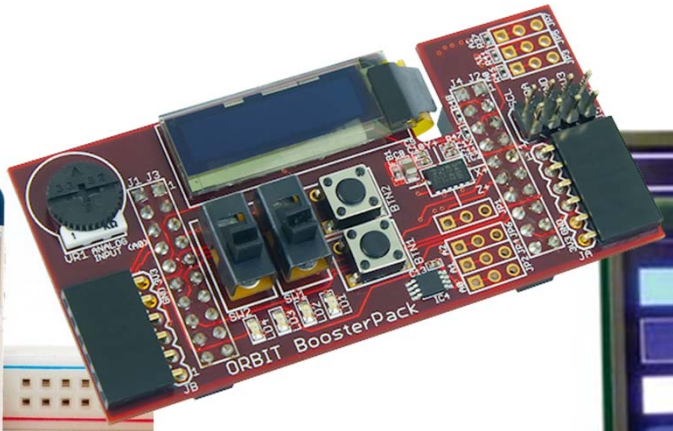
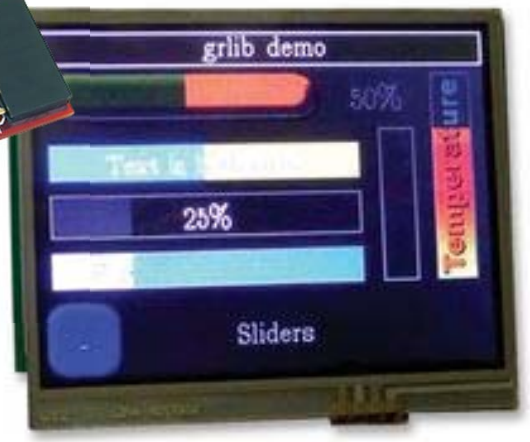
3. LaunchPad needs graphics

35-5 pins

35-7 pins





35-17 pins

Name	Pixels	Color	Cost (1)	Website
Graphic LCD 1.77" 84x48 - Nokia 5110, 5 pin, 8 wire	84x48	no	$10	https://www.sparkfun.com/products/10168
Sitronix ST7735R 18-bit color 1.8" TFT LCD display	128x160	yes	$19.96	http://www.adafruit.com/products/358
Orbit Booster Pack for the Stellaris	128x32	no	$30	https://www.digilentinc.com/
Kentec EB-LM4F120-L35 , 3.5 in, 15 pin, booster 320x240x16	320x240	yes	$35	www.newark.com 48W2063

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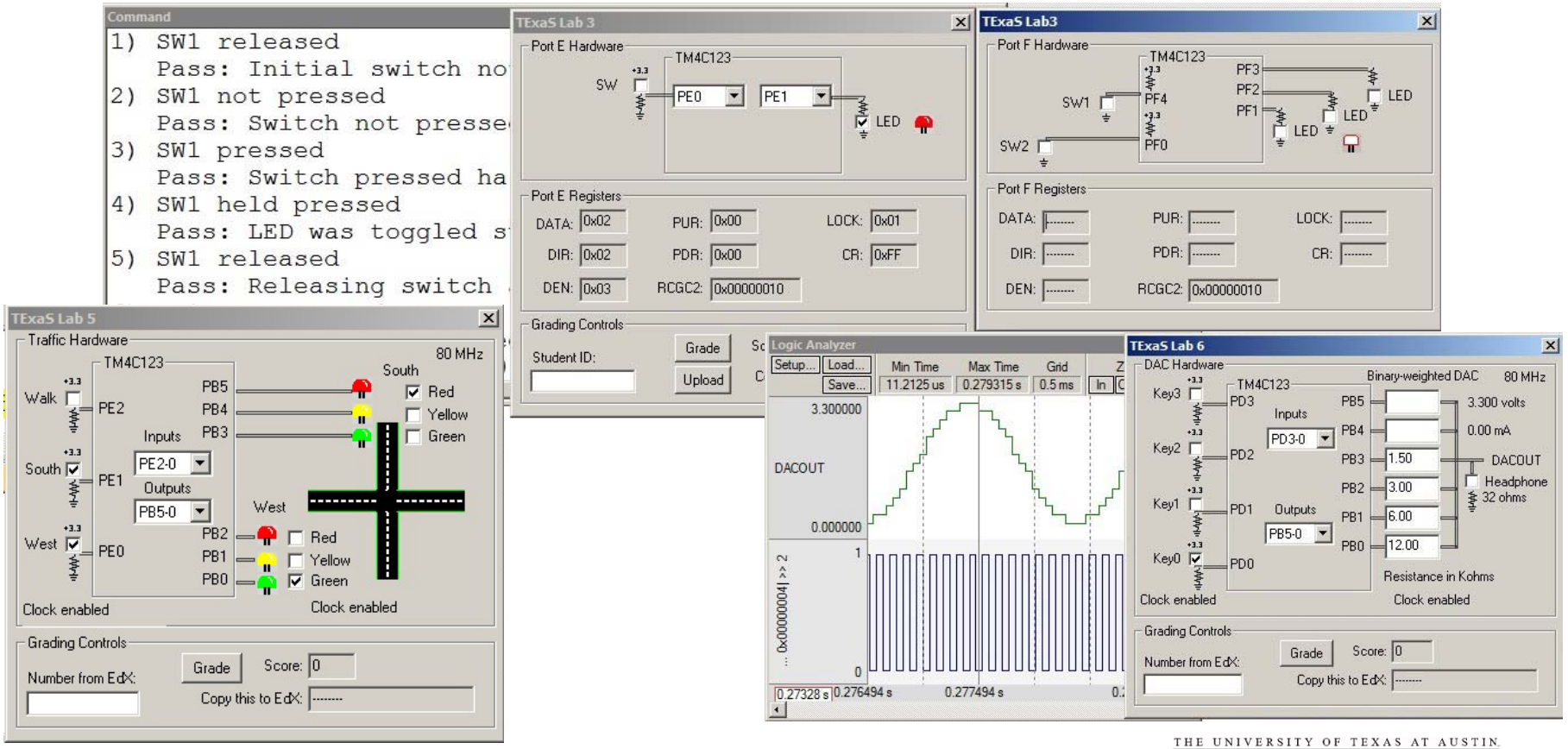
3. Applications

- Compiler, Simulator, Debugger
  - Texas Instruments Code Composer Studio
  - Keil uVision
  - TExaS *(simulation, grading, scope)*
- Circuit design and PCB layout
  - PCB Artist
  - National Instruments Multisim, Ultiboard
- Design tools
  - Texas Instruments Filter Pro

3. Boards, Books and Labs

Simulation of the Tiva LaunchPad



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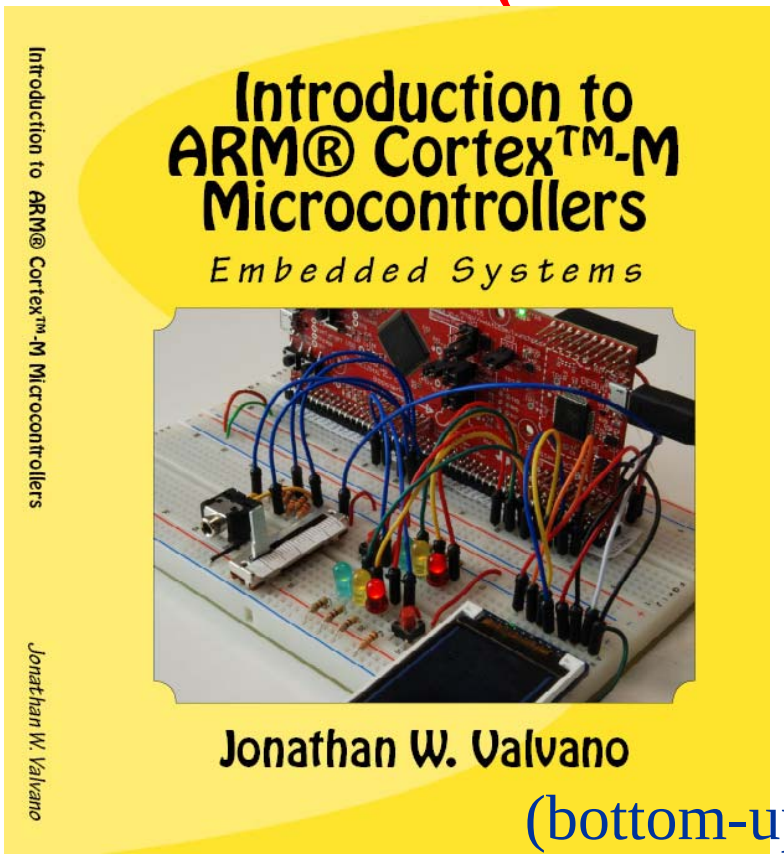
Available as DLL or source code

THE UNIVERSITY OF TEXAS AT AUSTIN
UT ECE
ELECTRICAL & COMPUTER ENGINEERING

3. Introduction to Embedded Systems

Volume 1 (freshmen EE or BME)



(bottom-up)

- Assembly or C programming
- Switch and LED interfacing
- Design and Debugging
  - Simulation, logic analyzer, scope
- Finite State Machine
- Local variables and stacks
- DAC output and interrupts
- LCD graphics interface, fixed-point
- ADC input, systems design
- UART and distributed systems
- Capstone design (video game)

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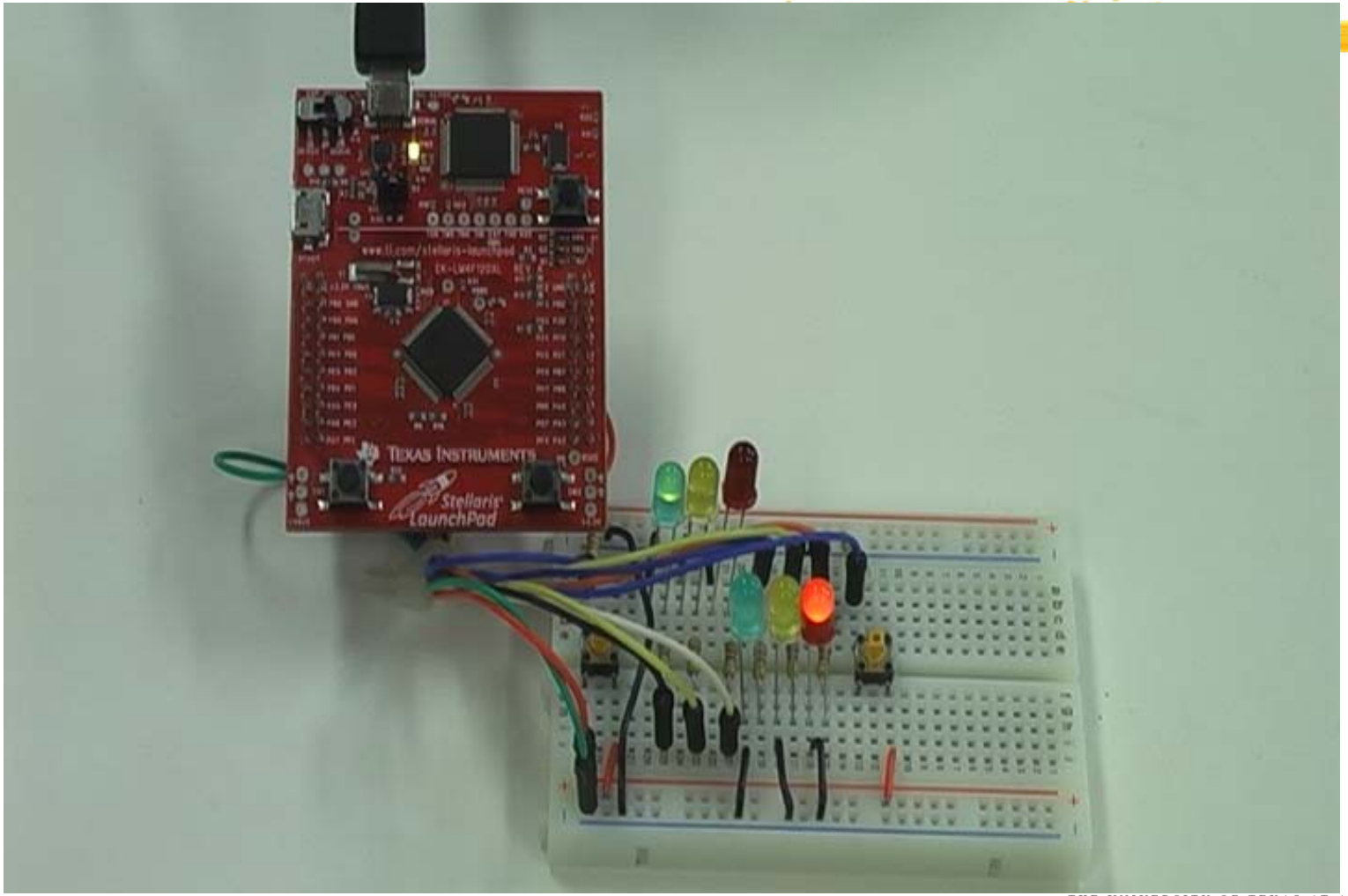
505 pages, $41

THE UNIVERSITY OF TEXAS AT AUSTIN UT ECE ELECTRICAL & COMPUTER ENGINEERING

3. Introduction to Embedded Systems



Embedded Systems – Shape the World

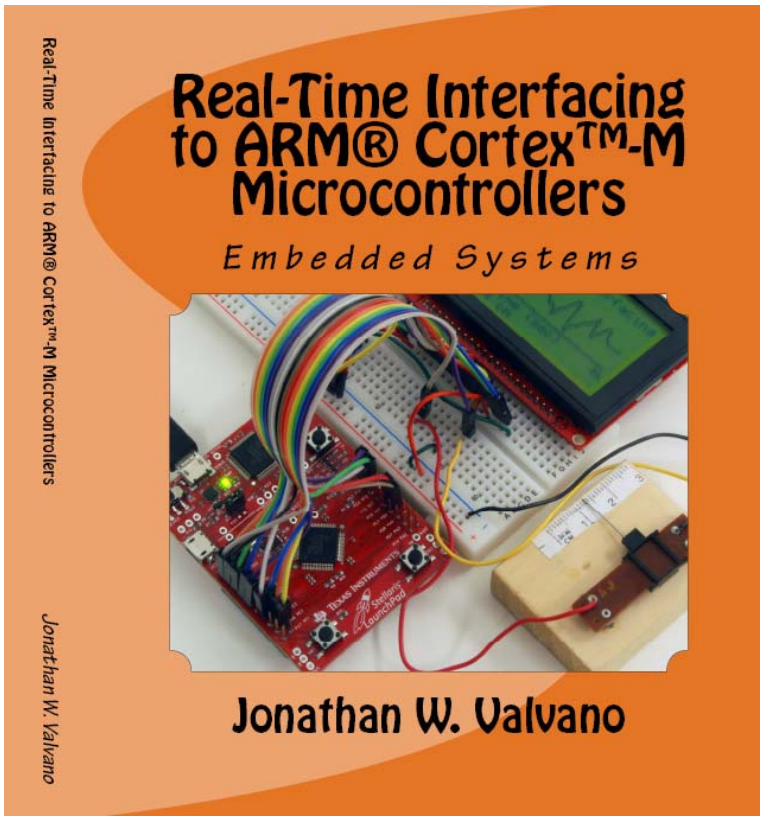
- What is and isn't a MOOC?
  - 41,329 enrolled
  - 6925 did a lab requiring a kit
  - 6.4% completed 70%
  - 8% completed 50%
  - 2/3 who started, finished
  - 91% approval rate

- Lab kit
- Teaching videos
- LaunchPad simulator, graders, voltmeter, scope

Physical kit increased completion rates

3. Interfacing and Systems

Volume 2 (junior EE)



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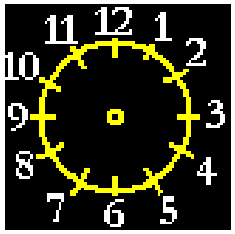
- Graphics device driver
- Hardware/software debugging
- Design and debugging
- Alarm clock
- Stepper motor
- Music player
- Temperature data acquisition
- Ethernet and wireless networks
- PCB layout, power
- Capstone design (open ended)



Kindle version

600 pages, $42

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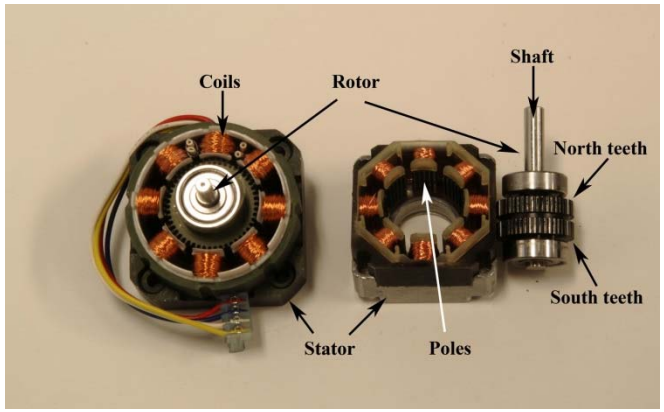
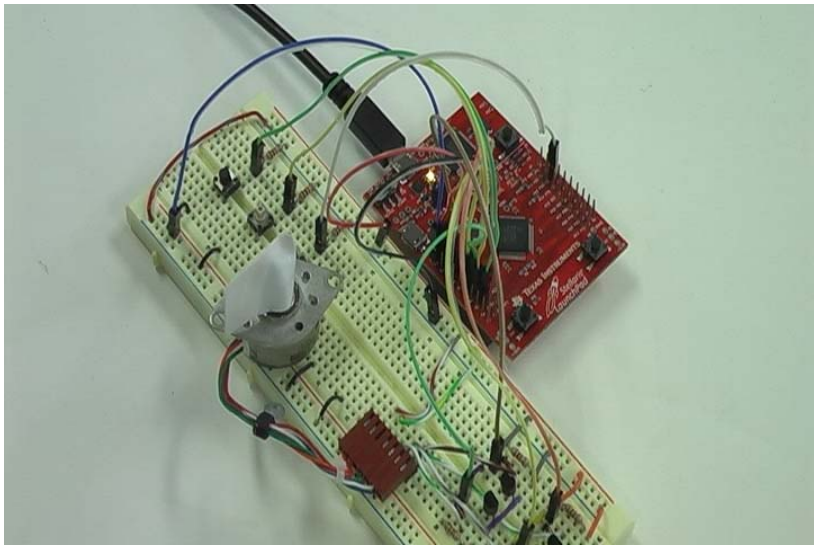
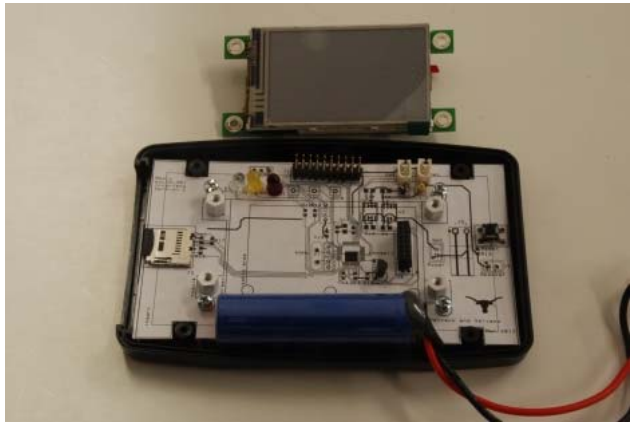
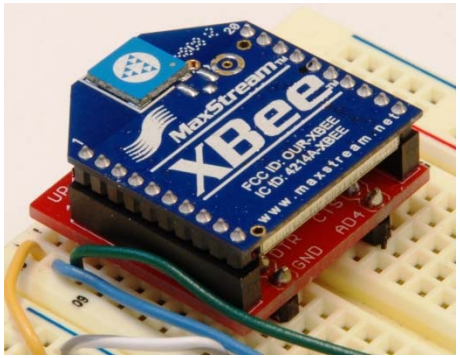
3. Interfacing and Systems

Volume 2 (junior EE)









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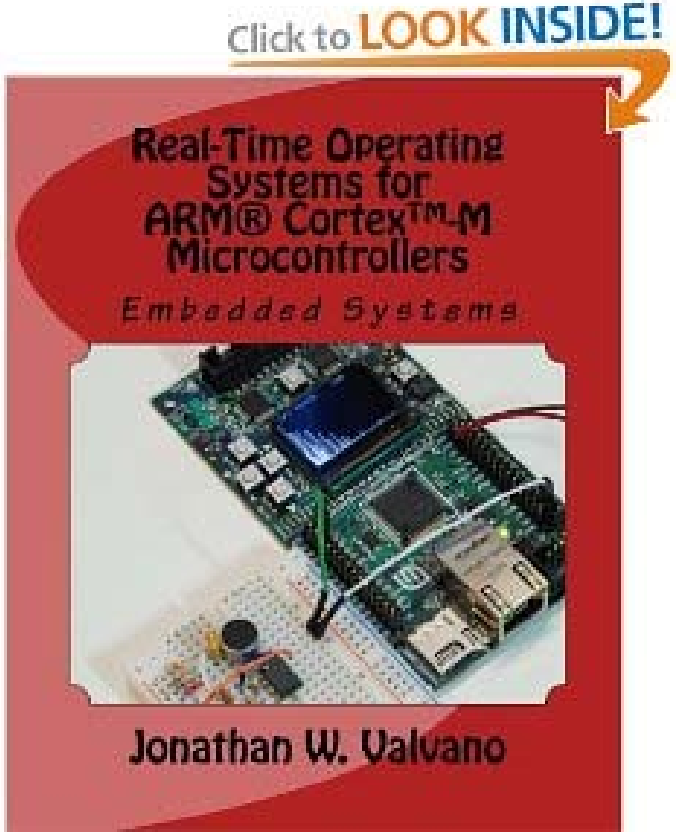
3. Real-Time Operating Systems

Volume 3 (senior/grad EE)



- Memory manager, device driver
- Thread switching RTOS
- Blocking semaphores
- Priority scheduler
- Digital and analog filters, FFT
- File system
- CAN or Ethernet network
- Autonomous robot racing

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400 pages, $38

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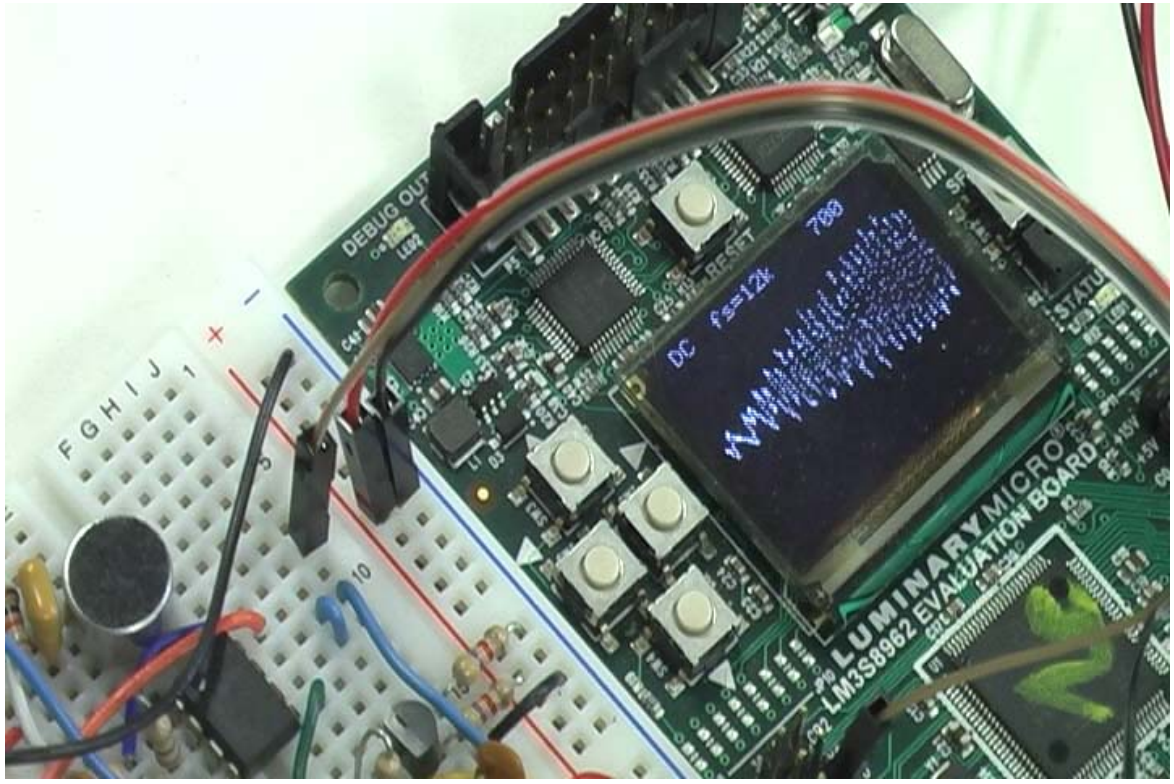
3. Real-Time Operating Systems

Volume 3 (senior/grad EE)



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3. Support for teaching

Web site (download and edit)

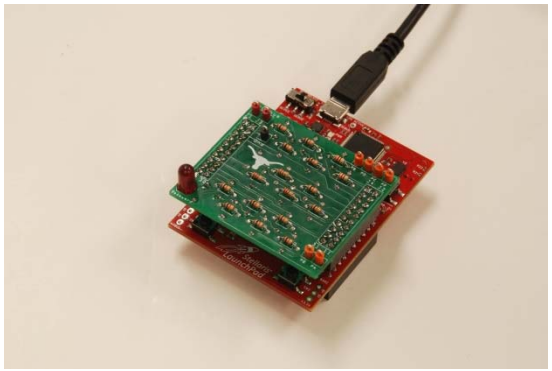
- Examples for LM3S811, LM3S1968, LM4F120, TM4C123, and TM4C1294
- PowerPoint slides
- Lab manual, data sheets
- **http://users.ece.utexas.edu/~valvano/**

EdX Course Spring 2014

Launchpad tester

Adopt a book →
Free parts for Launch

http://users.ece.utexas.edu/~valvano/arm/tester/



4. Successes: Competitions

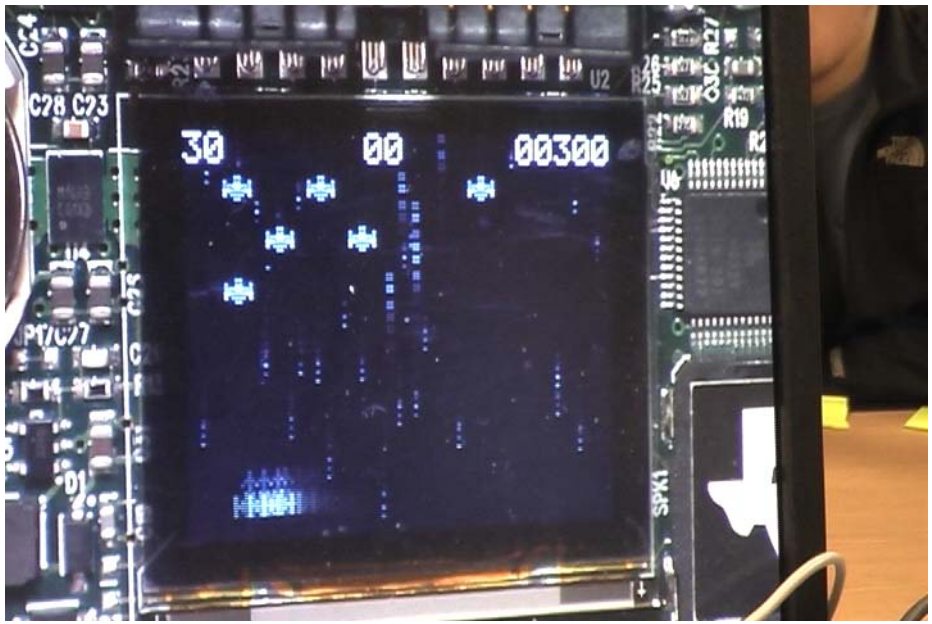
Students need to appreciate relevance

- Appropriate use of teams
- Build things that are fun to play with
  - Show off to friends, family, interviewers
- Competitions
  - Fun, intense
- Open-ended
  - Creativity, life-long learning, springboard

4. Competition

Volume 1 (freshmen EE or BME)

- Handheld game
- Peer review
- Teams of 2



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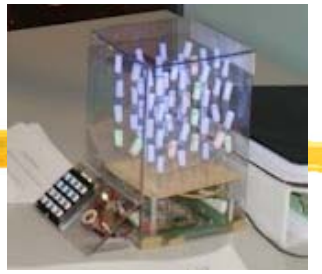
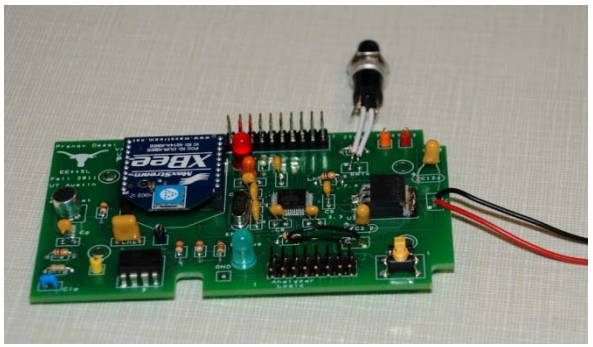
http://youtu.be/QxDQUUDStOw
http://youtu.be/z6_jlM2Y5qI

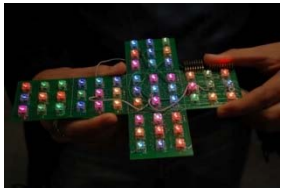
4. Competition



Volume 2 (junior EE)

- Requirements document
- Design cycle
- Design for test
- Systems Engineering
- Verification





http://www.youtube.com/watch?v=K9FD50qpGwg

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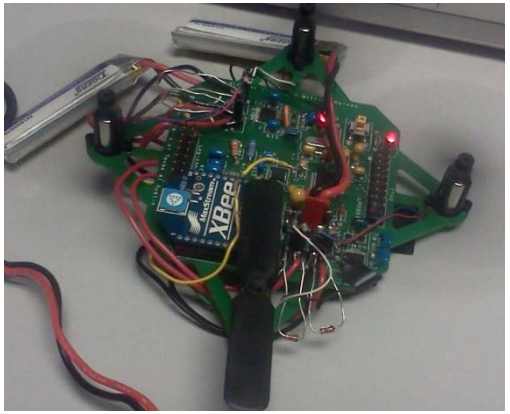
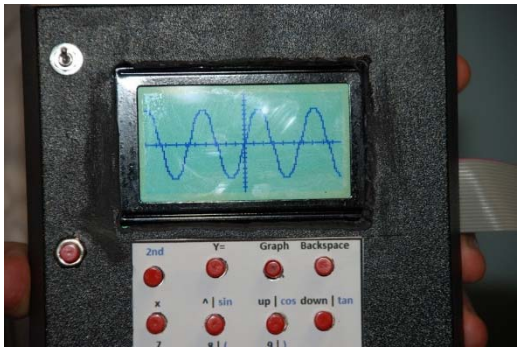
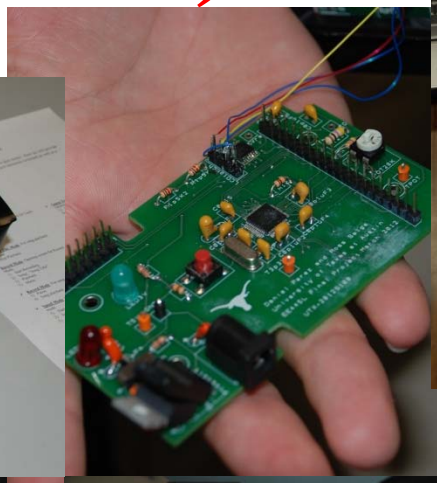
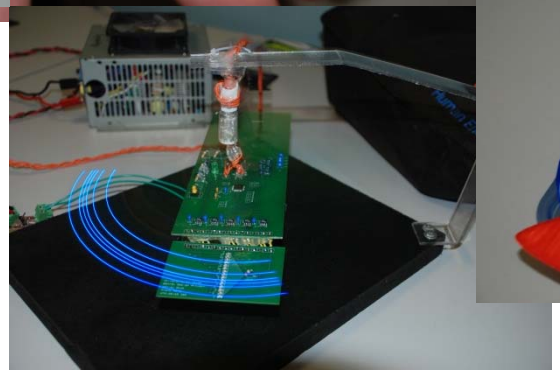




4. Competition

Volume 2 (junior EE)





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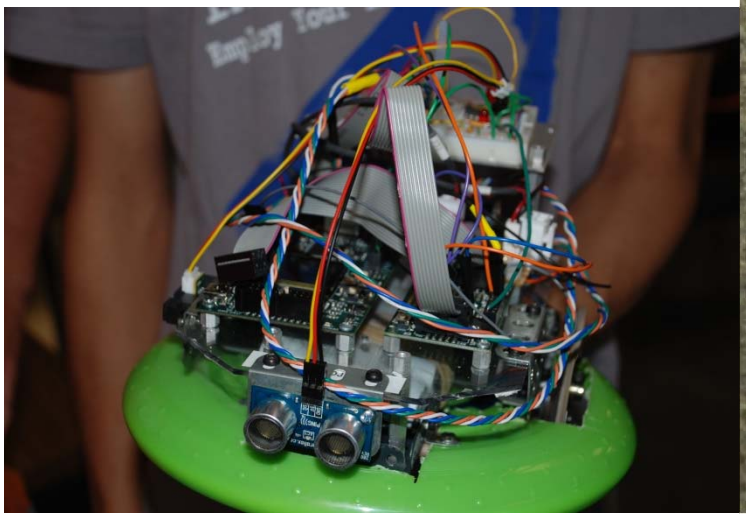
4. Competitions

Volume 3 (senior/grad EE)

- Autonomous Robot Racing
- Teams of four



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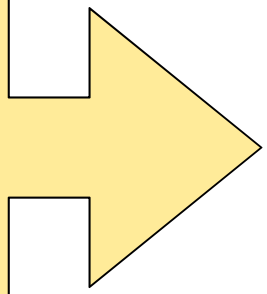
http://youtu.be/bZ1fXtN1T08
http://youtu.be/GKctvlvprAQ

5. Conclusions

- Bottom-up
- Lab-centered
- Empower students
- Motivate students
- Be flexible
- Be a team builder
- Make a plan and do it



Understanding
Design
Innovation

5. Interesting web sites

Example code

http://www.ti.com/tool/sw-lm3s
http://www.ti.com/tool/sw-ek-tm4c123gxl
http://users.ece.utexas.edu/~valvano/arm/
http://www.ti.com/tool/ek-tm4c123gxl

Free samples

http://www.ladyada.net/library/procure/samples.html

Compilers

http://www.ti.com/tool/ccstudio
http://www.keil.com/arm/mdk.asp

5. For more information

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http://users.ece.utexas.edu/~valvano/

EE319K Introduction

EE445L Interfacing and systems

EE445M Real-time operating systems

valvano@mail.utexas.edu

https://www.edx.org/course/utaustin/ut-6-01x/embedded-systems-shape-world/1172
http://users.ece.utexas.edu/~valvano/edX/
http://users.ece.utexas.edu/~valvano/Volume1/E-Book/VideoLinks.htm

Texas Instruments

univ@ti.com

6. Lab demonstration

- Install Keil uVision 4.7
  - –https://www.keil.com/demo/eval/armv4.htm
  - –Lab starter projects Keil\Labware
  - –Book example projects Keil\TExaSware
  - –TExaSdisplay
- Install TExaS, TExaS_Install.exe
  - –Install in same place as Keil
  - –http://edx-org-utaustinx.s3.amazonaws.com/UT601x/download.html

6. Lab demonstration

- Open Lab solution
  - –On USB drive H:\Lab13_DACSolution
  - –Double click project file Lab13.uvproj
- Project->Build Target
- Debug->StartDebugSession
  - –Debug ->Run
  - –Click on Key0 or Key1 or Key2 or Key 3
  - –Click on Grade