EE445L Embedded Systems Design Lab Spring 2014
Course Catalog Description Design of microcontroller-based embedded systems; interfacing from both a hardware and software perspective; and applications, including audio, data acquisition, and communication systems.
Class: **ENS 115**, TTh 12:30 – 2:00 p.m.
Office Hours (subject to change): TTh 11-12:30 and by appointment
Instructor: Bill Bard, ENS 436, 471-4802
email: **w.bard@utexas.edu** (put "EE445L" in the email title, send no ZIP files)
Course Web page: **courses.utexas.edu**
Required Text: Embedded Systems: Real-Time Interfacing to the Arm Cortex M3, 2011, ISBN: 978-1463590154
Equipment to buy: Every student will be required to have a Texas Instruments LM3S1968 kit by Friday 1/24. Since this is a new kit and we will be using the kit in EE319K and EE445L for a few years, you will have the option of selling it at the end of the semester. The first possibility is to buy or borrow a LM3S1968 kit from a previous EE319K/EE445L student. If you obtain a kit from a previous student, you will need the LM3S1968 board, USB cable, two male headers (soldered onto the board) and a solderless breadboard. If you do buy a board/borrow from another student, I recommend you let the TA test it to make sure the board is functional. The second possibility is to purchase a new Texas Instruments LM3S1968 kit, which includes a board, USB cable, two male headers (not soldered on) and solderless breadboard. The student cost will be $60.00 per kit plus tax and is available from edu.mouser.com. How to solder the pins on the connector. You will have to log in using a University of Texas email. Every student should own their own voltmeter and their own wire strippers. A voltmeter less than $20 will do, see BG Micro http://www.bgmicro.com/MET1014.aspx, or Jameco http://www.jameco.com/webapp/wcs/stores/servlet/Product_10001_10001_220812_-1 Harbor Freight has three locations around Austin and usually sells voltmeters for less than $10 http://www.harborfreight.com/7-function-digital-multimeter-90899.html. Since you will be making hundreds of solder joints this semester, we suggest you use the high-quality irons available on the second floor. However, all EE445L students will need their own voltmeter and wire strippers. The NI MyDAC you bought in EE302 can be used for as the voltmeter.
Lab: ENS252A
Unique Numbers:
16845 MW 930 to 1100 am
16850 TTH 930 to 1100 am
16855 TTH 1100 to 1230 p
16860 MW 330 to 500 p
16865 MW 500 to 630 p

Great TAs:
Victoria Bill victoriagbill@gmail.com
Mahesh Srinivasan srinimahesh@utexas.edu
Zichong Li zichonglig1@gmail.com

Reference materials on the web:
http://users.ece.utexas.edu/~valvano/EE345L/Labs/Fall2011/
Fall 2013 Laboratory Manual
http://users.ece.utexas.edu/~valvano/Datasheets Data sheets for devices used in EE445L
http://users.ece.utexas.edu/~valvano/arm/ Starter files for EE445L and EE345M
http://users.ece.utexas.edu/~ryerraballi/CPrimer/ C programming manual (for 9S12)
http://users.ece.utexas.edu/~valvano/EE345LFinal/ Old exams

Other references: For programming in C and digital logic, see the EE312 and EE31 6 texts
Prerequisites: EE312 and EE319K with a grade of at least C- in each; EE411 and EE313, or BME311 and BME343, with a grade of at least C- in each; and credit with a grade of at least C- or registration for BME333T, or EE333T.
Specific EE319K topics needed for EE445L: LED interface, switch interface, busy-wait synchronization, serial communication concepts (start bit, data bits, stop bit, baud rate, bandwidth), UART programming, analog to digital conversion (range, resolution, precision, accuracy), ADC programming, digital to analog conversion (range, resolution, precision, accuracy), interrupt concepts (arm, enable, acknowledge, vector), Output compare interrupt programming
Specific EE312 topics needed for EE445L: Modular programming, differences between pointers and numbers, when to use permanent allocation and when to use temporary allocation, definitions of **char**, **short** and **long**, understanding and use of **static**, **const** and **volatile**, understanding call by value versus call by reference, stack frames, structures, linked lists, fifo queues, verification. The most important component students must be able to accomplish is the translation of a problem statement into software code. The second most important skill we expect students to have is the ability to debug software.
Specific EE411/EE313/EE438 topics needed for EE445L: RLC circuits, NPN and PNP transistors, input impedance, output impedance, linear amplifiers using op amps, oscilloscopes, sampling, frequency response, Bode Plots, Fourier Transform, spectrum measurements.
Teaching philosophy: I strongly encourage students to take an active role in this class. Questions are welcome before, during and after class. Please feel free to email, visit or call me if you have questions.
Specific Objectives of EE445L The primary objective of EE445L is for the students to develop the ability to design microcomputer-based embedded systems. This class allows students to learn microcomputer interfacing from both a hardware and software perspective.
Microcomputer Architecture (EE319K review)
An Introduction to the Microcomputer, Architecture, The Cortex M3 Instruction Set, Cortex M3 Addressing Modes, Cortex M3 Instructions, I/O and Memory Organization, The Memory Map of the LM3S1968
Programming Microprocessors (EE312, EE322C review)
Data Structures in C (arrays, tables, linked lists, stacks, and fifo queues), Writing Quality Programs in C, Passing Parameters (Conceptual and Implementation Levels),

Modular Programming, Verification and Testing, Documentation

Microcomputer Bus Interfaces

Digital Hardware, Modules and Signals, Drivers, Registers, Timing equations, Timing diagrams,

Parallel and Serial Input-Output

LM3S1968 Parallel I/O Devices, Device Driver Software, Buffered Input and Output, Table and Linked List Interpreters, LM3S1968 Synchronous and Asynchronous Serial Input-Output, Synchronization in I/O devices, Blind-Cycle Synchronization, Busy-Wait Synchronization, Interrupt Synchronization, Polled Interrupts, Vectored Interrupts, Interrupt Priority

Parallel Port Interfaces

Keyboards, Key Debouncing, Keyboard Scanning Techniques, LED Scanning Techniques and LCD Interfacing

Data Acquisition Systems

Bridge circuits, op amps, low pass filters, instrumentation amplifiers, DAC, ADC, audio amplifiers

Motor interfacing

Stepper motors, DC motors, pulse-width modulation

Outcomes: After the successful conclusion of EE445L students should be able to design embedded systems including hardware/software interfaces for devices like LCD displays, motors, keyboards, analog sensors and speakers.

Attendance: Students are expected to attend lectures. The book covers more information than the class and we will use lectures to map our way through the book. If you miss class you may find it difficult to catch up.

Grading :

40% Laboratory assignment with a large weight applied to Labs 7, 8 and 11

20% Quiz 1, closed book, **Thursday, February 27**, 9:00 to 10:50 am, **ENS 115**

20% Quiz 2, closed book, **Thursday, April 17**, 9:00 to 10:50 am, **ENS 115**

20% Quiz 3, closed book, regularly scheduled time and place

When studying, focus on the topics that apply to the Arm Cortex M3 and the lab assignments. You will find old quizzes and finals with solutions on the professor Valvano's web site. I have no expected grade cutoffs or expected GPA for this class. All professors want a 5 on their teaching evaluation, and all students want an A. However, I feel both should only be awarded for excellence.

Safety warnings: Due to the lead in most solder, please wash your hands after soldering, before eating or drinking. If you drop the soldering iron, let it fall to the ground. Do not try and catch it. If you are pregnant or think you might be pregnant, have someone else do the soldering.

Lab Partners: All labs should be performed with a partner. You and your lab partner must be registered for the same lab section. The lab partnership must be registered with your TA (a simple hand written note signed by both students will suffice) during the week of **1/20** to **1/24**. Once registered, the partnership will continue. A partnership can be dissolved only after discussion with the TA. Both partners must be present during the demonstration. It is expected that both partners will contribute to all aspects of each lab, and both partners are expected to be present during the check out. The point values are the same for all labs. Lab partners will be selected in

your lab the week of **1/20** to **1/24**. If you want to switch sections, log your request onto the first page of the wiki. Once you find someone willing to swap sections, the two of you should go to an undergraduate advisor.

Laboratories

Lab 1. ASCII to fixed-point output to OLED
Lab 2. Debugging, oscilloscope fundamentals, logic analyzer, dump profile
Lab 3. Alarm clock, LCD, edge-triggered input interrupts, and SysTick periodic interrupts
Lab 4. Stepper motor, output compare interrupts, finite state machine
Lab 5.12-bit DAC, SPI, Music player, audio amp
Lab 6. Introduction to PCB Layout, PCB Artist (paper design only)
Lab 7. Design and Layout of an Embedded System
Lab 8. Software Drivers for an Embedded System
Lab 9. Temperature measurement, ADC, LCD
Lab 10. ZigBee, UART, distributed systems, key pad interface
Lab 11. Final Design and Evaluation of Embedded System

EE445L Laboratory Schedule (see your TA for the latest). Each week there are two 90 minute lab sessions, which are scheduled Monday/Wednesday or Tuesday/Thursday. You will show the preparation to your TA at the beginning of the second session. During the first session demonstrations will be made. The TA will sign your software listing when you demonstrate your system. The report (hardware/software/data plots) is due Friday uploaded to Blackboard according to the directions posted on Blackboard. Any EE445L TA is authorized to checkout your lab. Please consult with your TA for specific due dates for your lab section.

Lab Schedule *This is an approximate schedule, please check the website for the latest version.*

Week	First session	Second session	Friday (BB)	Comments
1/13	none	none		no lab activities, buy your LM3S1968 board, starting 1/13
1/20	Meet the TA**	partners chosen, 1 Prep		Keil uVision demonstration, PCB Artist (SCH) demonstration
1/27	1Demo	2 Prep	1 Report	Oscilloscope demonstration
2/3	2 Demo	3 Prep	2 Report	Logic analyzer demonstration
2/10	3 Demo	4 Prep	3 Report	Spectrum analyzer demo
2/17	4 Demo	5 Prep	4 Report	PCB Artist (PCB) demonstration
2/24	5 Demo	6 Prep		**Quiz 1 is 2/27**
3/3	6 Demo, 5 Report	7PrePrep	6 Report	
3/17	7 Prep		Rough draft	email SCH/PCB files to TA by 10am Friday 3/21
3/24	7 Demo	8 Prep	7 Report	final SCH/PCB files due on BB at 10am Thursday 3/27
3/31	8 Demo	9 Prep	8 Report	Lab 8 report is just the software
4/7	9 Demo	10 Prep	****9 Report**	****Due to the test, Lab 9 report is due Monday 10 am****
4/14	10 Demo			**Quiz 2 is 4/17**
4/21	11 Prep,10 Report			Complete 11
4/28		11 Demo	11 Report/Expo	Turn in equipment by 5/2

"8 Demo" means your PCB Artist files are delivered to the TA
****No MLK Day lab 1/20 (make sure you go to the second session)**
Prep = you turn in your lab preparation
Demo = you demonstrate your lab to the TA
Partial = you demonstrate first part of a two-week lab to the TA
Report = you turn in your complete lab report to the TA

PCB files due Thursday 3/27 10am
TA downloads files from BB and creates an XLS sheet
PCB ordered on Thursday 3/27 by 12 noon
Boards received Tuesday 4/8.

Option 1, give PCB with bare LM3S811 processor to students
Option 2, give PCB+LM3S811 to technicians on 2nd floor for oven soldering
Tuesday -Friday they will solder LM3S811 onto PCB
Friday 4/11 or Monday 4/14 PCB with processor soldered returned to students
Lab 11 prep 4/21 or 4/22 all parts soldered and microcontroller can be programmed.

During the week of 1/20 to 1/24, please go to your scheduled EE445L lab sessions in ENS252A to get a demonstration of the lab equipment. If you do not already own a LM3S1968 board, you must purchase one. Boards can be purchased for $60 from Mouser (come to class to get details). Each student should have their own board. The lab preparations (hardware diagrams and syntax-free software source code printouts) are due at the beginning of your lab period. In other words, please type your software into the PC before lab. Attendance in lab is required. All software for lab, and tests must include comments. All hardware must include R&C values specifying tolerance and type (e.g., 5% carbon), and chip numbers (be very specific e.g., INA122P). Pin numbers are required only for lab, not for the exams.

Students are encouraged to go to the last 1 hour of the other lab periods, but the first priority will be to the regular students. During the first 15 minutes of lab, the TA will collect preparations. For the next 15 minutes, the TA will lead a lab discussion session. The remaining lab time is available for debugging and lab checkout. At the end of the semester please verify with the checkout counter that your record is clear. All reports must be given to the TA by Friday 2 May, 2pm.

This is an approximate schedule, please check the website for the latest version.

Week	Chapter	Topic
1/14	1, 2	Arm Cortex M3 architecture, features of the LM3S1968, fixed-point
1/22	2, 3	Lab environment, **Lab1** project , example decimal fixed point, debugging techniques, call graphs, flow charts, data flow graphs, **Lab2** project, debugging techniques, and programming style, dumps, monitor
1/27	2,3, 4,5	Draw pictures showing elements on the stack for uVision compiler, show stack frame during interrupt service, debugging from an assembly language perspective, real time systems. Interface binary switch using pull-up resistor to an input port, draw flowchart of **SysTick** project, profiling with the scope showing just how small a percentage of time is spent in the background, globals/locals, static variables, threads, draw thread trace
2/3	9	Profiling, oLED Displays, blind cycle versus gadfly synchronization, show how to maintain time of day in **Timer**, allocation of tasks between the foreground and background. Digital logic, input/output voltage/current, NPN transistor interface of a speaker, capacitive and inductive loads
2/10	4,5	Linked data structures, ROM-based structures using const, finite state machines, **Moore** project, fixed time delay using Timer interrupts, adding output pins, adding input pins, running the FSM in the background using interrupts. FSM with functions, traffic example, stepper motors, full-step versus half-step algorithm, stepper interface electronics (L293, TIP120, IRF540), snubber diodes
2/17	8, 9	SSI/DAC interface, signal generation, Timer interrupts, real-time systems, MC34119 audio amplifiers
2/24	9	Sound waves – **Quiz 1 review Tuesday, Quiz 1 Thursday**
3/3	9	Embedded system layout, power, clock, reset, packaging
3/17	9,	Low power design, Guest lecture, Resistance bridge, instrumentation amplifier, Butterworth filters
3/24	8	Data Acquisition Systems, Nyquist Theorem, Aliasing, FFT
3/31	10	Sampling Jitter, Input capture
4/7		Fifo queue analysis and robust software, MSP430
4/14	Lec22.pdf	Level conversions - **Quiz 2 review Tuesday, Quiz 2 Thursday**
4/21	11,	XBee, Wireless communication
4/28		Cryptography

Legal Stuff: The 12th class day is 1/29. The drop policy is extremely complicated. See your academic advisor or the Dean of Students for more information. Course evaluation is conducted on the last class day in accordance with the Measurement and Evaluation Center form. The final exam is at the time and place stated in the course schedule. The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students with Disabilities at 471-6259, 471-4241 TDD.

Religious Holy Days By UT Austin policy, you must notify me of your pending

absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, I will give you an opportunity to complete the missed work within a reasonable time after the absence.

Scholastic dishonesty: "Faculty in the ECE Department are committed to detecting and responding to all instances of scholastic dishonesty and will pursue cases of scholastic dishonesty in accordance with university policy. Scholastic dishonesty, in all its forms, is a blight on our entire academic community. All parties in our community -- faculty, staff, and students -- are responsible for creating an environment that educates outstanding engineers, and this goal entails excellence in technical skills, self-giving citizenry, an ethical integrity. Industry wants engineers who are competent and fully trustworthy, and both qualities must be developed day by day throughout an entire lifetime. Scholastic dishonesty includes, but is not limited to, cheating, plagiarism, collusion, falsifying academic records, or any act designed to give an unfair academic advantage to the student. The fact that you are in this class as an engineering student is testament to your abilities. Penalties for scholastic dishonesty are severe and can include, but are not limited to, a written reprimand, a zero on the assignment/exam, re-taking the exam in question, an F in the course, or expulsion from the University. Don't jeopardize your career by an act of scholastic dishonesty. Details about academic integrity and what constitutes scholastic dishonesty can be found at the website for the UT Dean of Students Office and the General Information Catalog, Section 11-802."

You are encouraged to study together and to discuss information and concepts with other students. You can give "consulting" help to or receive "consulting" help from such students in oral form. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an email, an email attachment file, a portable storage device, or a hard copy. Copying of any part of a program is cheating without explicit reference to its source. We do enter lab assignments turned in by EE445L students through a plagiarism checker, comparing them to assignments of this and previous semesters. If we find two programs that are copied, there will be a substantial penalty to both students, e.g., failure in the course. Students who cheat on tests or in lab will fail. Prosecution of cases is very traumatic to both the student and instructor. It is appropriate to use software out of the book, class website as long as all copy-pasted software is explicitly referenced. Copy-pasting software from current or past students is scholastic dishonesty. Policies concerning the use of other people's software in this class:

- I strongly encourage you to study existing software.
- All applications and libraries must be legally obtained. e.g.,
  You may use libraries that came when you bought a compiler.
  You may use software obtained from the web.
  You may copy and paste from the existing source code.
- You may use any existing source code that is clearly referenced and categorized:
  original: completely written by you,
  derived: fundamental approach is copied but it is your implementation,
  modified: source code significantly edited to serve your purpose,

copied: source code includes minor modifications.

The University Honor Code is "The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community." http://registrar.utexas.edu/catalogs/gi09-10/ch01/

Request samples (DIP or PDIP package) The parts labeled 1) 2)... 9) will be requested for you. In other words, we will make one request for the entire class. However, keep these web sites in mind as you design your Labs 8, 9,11. **Do not order anything now; wait until you design Lab 8, and then order what you need.** You will need to register with an official University email address (e.g., YourName@mail.utexas.edu) rather than a junk email address (e.g., aol.com or gmail.com). For general information on getting free samples, see http://www.ladyada.net/library/procure/samples.html**.**

http://www.analog.com/en/index.html Analog Devices
AD8032ANZ rail-to-rail op amp

http://www.maxim-ic.com/ Maxim IC
1) MAX5353ACPA+ or MAX5353BCPA+ single 3.3V-powered, 12-bit SPI interface DAC (ACPA or BCPA)
MAX552BCPA 12-bit multiplying DAC
MAX1246ACPE+ 3.3V-powered, 12-bit ADC, such as the (A or B, with or without +)
MAX5155ACPE dual 12-bit SPI interface DAC (ACPE or BCPE)

http://www.ti.com/ Texas Instruments
2) INA122P rail-to-rail instrumentation amp
3) OPA2350PA rail-to-rail dual op amp
4) LM4041CILPR adjustable shunt reference
5) TLV5616CP 12-bit DAC (or TLV5616IP)
6) LM3S1968-IQC50-A2
TLC2272ACP rail-to-rail dual op amp
TLC2274ACN rail-to-rail quad op amp

http://www.samtec.com/ SamTec connectors
7) BCS-120-L-S-TE (need 1 for the $20 graphics LCD from Sparkfun)
8) BCS-114-L-S-TE (need 1 for LCD from checkout)
9) TSW-133-09-F-S-RE, TSW-133-08-F-S-RA, (used for EKK-LM3S1968)

Search engine for parts http://octopart.com/
Game engine http://www.3dgamestudio.com/
Hobby parts http://www.sparkfun.com/
Surplus http://www.allelectronics.com/ http://www.bgmicro.com/

Full line http://www.digikey.com/ http://www.mouser.com/
http://www.newark.com/

Put your embedded system in a box (not free, but a good source for choices)
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