From Scratch to System: A Hands-on Introductory Embedded Systems Course

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Background

Boise State University − 19,800+ students

College of Engineering − 13th anniversary

Electrical and Computer Engineering

- Started in 1997/98, Ph.D, M.S., M.S.Engr., and B.S. Degrees
- Currently 225+ undergraduate, 80+ graduate students
- 16+ faculty

Introduction

- Observed the need to update microprocessors and embedded systems courses
  - Students lacking software skills to effectively demonstrate hardware functionality in advanced courses
- Microprocessors course was updated in 2007
  - Assembly and C programming
  - Modern IDE
- This presentation (and paper) discusses the updated embedded systems course

Old Format

- Even though the department is fairly young, this course was outdated very quickly
  - No effort in keeping it updated!
- Embedded Systems (old format)
  - Two parts: lectures and end-of-semester project
  - Lectures concentrated on
    - Features and capabilities of microcontroller
    - Assembly only programming
    - Device-to-device communication protocols
  - End-of-semester project
    - ~4 weeks
  - Microchip PIC 18Fxxxx

Objectives of the update

- Employability
  - Able to take a design from idea to prototype
- Able to work with hardware and software
  - Interfacing
  - Coding

Current Format

- Meet twice a week for 1 hour 15 minutes each
- Project-based laboratory assignments
- Lectures are given when a need arises
- Two tests
  - Beginning of the semester
  - Third quarter of the semester
- In the first two offerings
  - An off-the-shelf Microchip development board was used
  - Students were given devices and sensors

Current Format (cont)

- In the latest offering (Fall 2009)
  - No off-the-shelf board
- Microchip 18F4620 was used
- Students are provided with all necessary devices and sensors, except the programmer
  - PicKit2 Programmer (~$35)
- Use of Agilent Mixed Signal Oscilloscopes (model MSO7104A) and power supplies
- Two written assignments
- Seven hands-on assignments
- Project (4 to 6 weeks)

Does it work?

- Each assignment has two check-offs
  - Demonstration check-off
  - Code check-off (email)

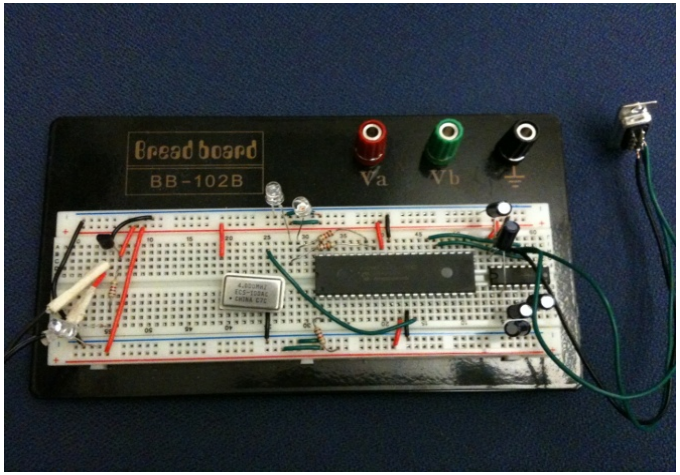
Beginning of Semester Test

- Objective: to gauge programming skills
  - Problem in struct, union, and pointer
  - Two take home problems
    - Bubble sort
    - Quick sort

```
#include <stdio.h>

char HEXCHAR[] = "0123456789abcdef";

int main()
{
   unsigned int val = 0xa5b4c3d2;
   char ch;

   ch = HEXCHAR[ (val>>17) & 0xf ];
   printf ( "==>%c\n", ch );

   return 0;
}
```

Assignments

- Writing assignment 1
  - Microcontroller survey
- Hands-on assignment 1
  - Microchip from scratch
    - PIC18F4620
    - LEDs
    - Wall power supply
    - RS232
    - Programming port

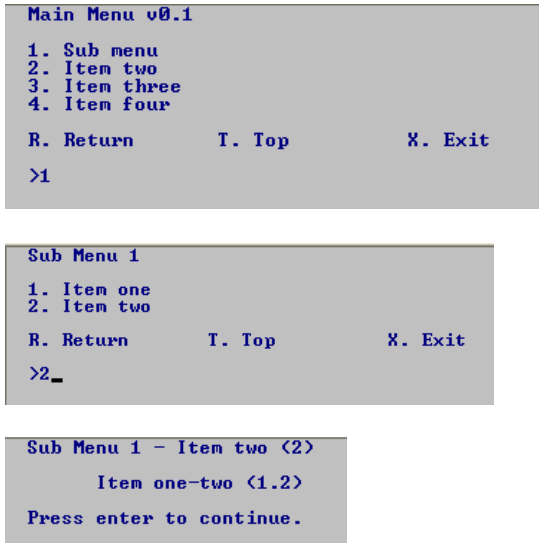


Assignments

- Writing assignment 2
  - Write-up the role of each component in Microchip from scratch assignment
- Hands-on assignments 2-4
  - On-chip analog-to-digital converter
  - Thermistor
  - ADC chip with SPI

Assignments

- Hands-on assignment 5
  - Printed-circuit board design with Eagle
- Hands-on assignment 6
  - Embedded menu
- Hands-on assignment 7
  - I^2C DAC



Mid Semester Test

- Question on:
  - Op-amp
  - Voltage divider
  - Microcontroller reset circuitry
  - Skeleton code for ADC, I^2C, or SPI interfaces

Outcome - Positive

"The lectures give some preliminary information, and then the labs let you get your hands dirty. This seems to be very effective for learning, especially when you must struggle with a lab."

"Doing the 'PIC from scratch' on a prototype board was much better than using a purchased development board. Now, I feel confident with acquiring just a microcontroller chip and making something useful with it. I also learned how to use clock modules, design practical op amp circuits, and some things to avoid when using an ADC."

Conclusions

- This course has been taught three times
- The most current offering (4^{th}) is on-going with Atmel microcontroller
- Students demonstrated the ability to interface device/ sensor to microcontroller
- Students demonstrated the ability to code in C and use of libraries
- The challenge of this approach is complexity
  - The questions and problems can be overwhelming

Questions?