EE 316 - Introduction to Embedded Microcontrollers

Designation: Required core course for electrical engineering majors.

University Bulletin Description: EE 316 (3) Introduction to embedded microcontrollers in electronic and electromechanical systems. Hardware and Software design techniques are explored for user and system interfaces, data acquisition and control.
Prerequisites: CMPSC 201 or CMPSC 121, CMPEN 271, EE 210; Prerequisite or Concurrent: EE 310.

Prerequisites by Topics:
1. Understanding the development and implementation of algorithms
2. Understanding the use of flowcharts to outline the operation of an algorithm
3. Understanding the operation of combinational and sequential logic system operation
4. Understanding the binary & hexadecimal numbering systems
5. Understanding the operation of simple op-amp & comparator circuits
6. Understanding the use of a transistor as a switch (BJT & MOSFET)

Textbooks, Paperback Books, Datasheets and Handouts:

(Required): Microchip PIC18F4620 Microcontroller Datasheet, Microchip Staff, Microchip Technology Inc, 2004, **DS396226B**

(Required): Instructor Handouts Regarding Assembly Code, the **PIC-Pro Programming Language** and the **CCS C-code Programming Language**

(O*ptional*): **Embedded Design with the PIC18F452 Microcontroller**, First Edition, John B. Peatman, Prentice-Hall, 2003, **ISBN# 0-13-046213-6**

(O*ptional*): **Programming PIC Microcontrollers with PIC-Pro**, First Edition, Chuck Hellebuyck, Newnes, 2003, **ISBN# 1-5899-5001-1**

(O*ptional*): **PIC-Pro: Programming and Projects**, First Edition, Dogan Ibrahim, Newnes, 2001**, ISBN# 0-7506-5229-2**

(O*ptional*): **PIC Microcontroller Project Book**, First Edition, John Iovine, Mcgraw-Hill, 2000, **ISBN# 0-07-135479-4**

(O*ptional*): **PICmicro MCUC**, An Introduction to Programming the Microchip PIC in CCS C, Nigel Gardner, Bluebird Electronics, 2002, **ISBN# 0-9724181-0-5**

(O*ptional*): **Embedded C Programming and the Microchip PIC**, Barnett, Cox, & O'Cull, Thomson-Delmar Learning, 2004, **ISBN# 1401837484**

(O*ptional*): **C++ Programming in Easy Steps,** Mike McGrath, Barnes & Noble Books, 2005, **ISBN# 0-7607-7138-3**

Homework:
The EE 316 Experimentation Board has many different embedded controller based analog functions. Each student will write CCS C-Code, and PIC-PRO Microcode to control, regulate and monitor each of these analog functions. Initially, some programs will be assigned to be written in Assembly Language. The purpose of each Homework Assignment is to allow the student time to develop the necessary skills that will be needed to successfully perform each laboratory experiment and pass each exam.

Learning Outcomes:
All electrical engineering graduates are expected to have knowledge of digital systems, which includes familiarity with embedded microcontrollers. The goals of EE 316, Introduction to Embedded Microcontrollers, are for the student
1. to be able to show the data flow through a microprocessor when a program is executed,
2. to be able to write the code that will perform a task based on a word description of a problem,
3. to be able to show how the I/O functions of a microcontroller and the external devices that are driven by the microcontroller operate,

4. to be able to analyze hardware interface circuits which connect the I/O Pins of a microcontroller to external devices based on a word description of a problem,
5. to be able to create effective technical communications in a written lab report.

Topics:

1. Fundamentals, Numbering Systems, Digital Logic Systems
2. Microcontroller Architecture, Instructions, Flash Memory, EEPROM Memory, RAM
3. Assemblers & Higher Level Program Development Language Tools
4. Assembly Code, CCS C-Code, PIC-Pro Code
5. Parallel & Serial I/O, Interrupts, Timers, Pulse-Time Capturing, Pulse-Width-Modulation
6. Sampling, Analog-to-Digital & Digital-to-Analog Converters
7. Reading from I/O Ports & Writing to I/O Ports
8. Delay Loops & Subroutines
9. Logical, Arithmetic and Bit-wise Operations
10. Analog Hardware Interface Circuits:
    (BJT & MOSFET Switches, Op-Amp, Voltage Regulator, Relay, LED's & Motor Drive)
11. Principles of the Digital Low-Pass-Filter
12. Frequency and Phase Modulation Hardware and Software Principles
13. The Microcontroller Comparator and Voltage Reference Hardware & Software Module

Goals: Upon completion of this course, the student should be able to:

- Write an effective program for any PIC Microcontroller using, Assembly Code, CCS C-code and the PIC-Pro Programming Languages.
- Understand the Hardware Architecture, Memory and Register Structure of a Microcontroller.
- Analyze a variety of Analog Circuits which will efficiently interface with a Microcontroller.
- Understand how Light-Emitting-Diodes, Mechanical Switches, the Telephone Keypad and a Liquid-Crystal-Display create a human interface with an Embedded Microcontroller.
- Understand the way one can use a Embedded Microcontroller to do the following:
- Digitally Control the Position, Speed and Direction of Rotation of a Stepper Motor
- Digitally Regulate the Speed of a Brushless DC Motor
- Digitally Measure DC-Voltage, and Resistance
- Communicate with a computer over the RS232 Serial Port
- Communicate between a Microcontroller and an I2C Device
- Digitally Control a Real-Time Clock/Calendar device
- Digitally Measure Temperature
- Digitally Generate Piecewise Linear Waveforms
- Digitally Regulate the Output Voltage of a DC Switching Voltage Regulator
- Generate a Variable Moving Average Digital Low-Pass Filter for use in the Audio Spectrum
- Digitally Control the Operation of High Voltage DC and AC Devices, through a Relay Circuit
- Generate Frequency and Phase Modulated Signals

Computer usage:

This course studies the operation of embedded microcontrollers and considers both software and hardware aspects of microprocessor operation. Personal Computers are used for code compilation, simulation of program operation, downloading of code to the target microprocessor, and control of the microprocessor during debugging. Word processing is used in preparing the laboratory reports.

PIC18F4620 Microcontroller Hardware Structure:

1. 4K General & Special Purpose Registers
2. 33 I/O Pins combined over 5 I/O Ports
3. 36 Special Purpose I/O Port Circuits
4. 6 Oscillator Configurations (40Mega Hertz Maximum)

5. Flash Program Memory (32K by 16 Bits)
6. Random-Access-Memory (4K by 8 Bits)
7. Non-Volatile Data EEPROM (1K by 8 Bits)
8. 13 Port, 10-Bit Multiplexed Analog-to-Digital Converter with 3 ADC Configuration Registers

Class/laboratory schedule: two 50-minute lectures, one 180-minute laboratory per week
Laboratory Experiments based on the PIC18F4620 Microcontroller:

1. "Loop Timing & Serial RS232 Computer & PIC-to-PIC Communications"
2. "Keypad, Light-Emitting-Diodes, Liquid-Crystal-Display, Relay Control and Sound Generation"
3. "Digital Brushless-Fan Speed Regulator"
4. "Digital Voltage Regulator"
5. "Digital 4-Phase Stepper Motor Controller"
6. "Electronic Thermometer"
7. "I2C Real-Time Programmable Clock/Calendar"
8. "Digital Volt-Ohm Meter and Frequency Counter"
9. "Digital Function Generator"
10. "Variable Bandwidth Digital Low-Pass-Filter"
11. "Frequency and Phase Modulation"

Written Laboratory Reports:
Each student is required to submit a written Laboratory report upon the completion of each laboratory experiment and submit it for grade before the beginning of the next laboratory experiment.

Contribution to Meeting the Requirements of Criterion 5. Curriculum:
This course contributes to both the engineering topics and design components. The course requires the student to understand the use of a small microprocessor to acquire data, process information, and control some output. This course is devoted the design of both the software and hardware elements of a microcontroller system.

Relationship to Program Outcomes:
O.1.1. Graduates will possess mathematics skills necessary for electrical engineering.
O.1.3. Graduates will have attained computer proficiency.
O.2.1. Graduates will understand how to analyze and design simple electrical/electronic circuits.
O.2.2. Graduates will understand electronic devices.
O.2.3. Graduates will understand the basic concepts of linear systems and how they interact with continuous-time signals.
O.2.5. Graduates will have knowledge of digital systems.
O.4.1. Graduates will interact with industry both within and outside of a classroom setting.
O.5.1. Graduates will have good teamwork skills.

Prepared by: Sal R. Riggio Jr., **Date:** 3-12-08