ME499 Self-Paced Instrumentation Lab:

Introduction to Research Instrumentation Laboratory With web-based tutorials

"Start when you're ready, stop when you're done, and enjoy the process along the way."

The objective of this course is to enable students with no prior experience to design, build, and test useful electronic circuits. By the end of the course, students should be able to understand how most simple electronic circuits function, and they should be able to find resources and further information to improve their circuit design skills.

Basic assumptions:
You are interested in learning to build electronic circuits.
You don't mind occasionally failing, and will continue to work until you succeed.

Here's how it works:
This is a self-paced introductory course open to all students interested in circuit design.

1- You sign up for the course for an appropriate number of credits (see below).
2- Arrange for lab access, lab user times, and meeting times with instructor.
3- You select an appropriate Module to study (see list below). Start with Module 01.
4- Go to the Web, download and study the appropriate Module:
   (http://www-personal.umich.edu/~bobden/bob_me499.html)
5- Take a quiz based on the contents of the module you just studied.
NOTE: No quizzes Winter 2003: course is still under development.
6- If you FAIL, GOTO STEP 4 and REPEAT, otherwise, go to STEP 7
7- Prepare for the Laboratory (each module will tell you how to do this)
8- Go to the Lab and follow the instructions for that module.
9- Feel free to do as much as you like, experiment, etc.
10- SAVE the circuits that you build, along with any supporting material
   (such as sketches, printouts, notes, failed attempts, etc.)
11- Show all of the stuff you built to the instructor so you can get credit.
12- Help to improve the course: provide feedback on each module by filling out the evaluation form at the end of each module. Excellent and thoughtful feedback will improve the course, your grade, and the world in general.
13- For each module, your grade will depend on how far you progress.

The instructor will be in the laboratory and available for questions for several hours each week, as agreed upon at the beginning of each term. Generally, you can seek help from any source (other students, professors, internet tutorials, Psychic Friends, up to you…) while building and testing your circuits.

Prerequisites:

For the first "experimental" term we are requiring that each student have (or be currently taking) EECS 314. The suggested prerequisites for the course are two terms of introductory physics and two terms of calculus. You can get by without these prerequisites, but in that case you will simply need to do a bit more work up front, and may also need to take some of this material "on faith". Prior experience with computer programming is valuable for several of the modules involving data acquisition and embedded microcontrollers. Certain advanced modules may require prior completion of introductory modules.

Course Requirements/Credit/Grading:

Students will be required to pass a brief web-based exam on each module topic before they will be permitted to carry out the module in the lab. Instructors will check to be sure that this requirement is met before the student will be permitted to check out the necessary equipment for each module.

Assignment of Credit:

Final credit will be based upon the number of modules completed.

For Undergraduates:	**For Graduate Students:**
4 modules = 1 credit	5 modules = 1 credit
8 modules = 2 credits	10 modules = 2 credits
12++ modules = 3 credits	15++ modules = 3 credits

Students will register for the course in anticipation of a predicted level of effort, and credit will be assigned accordingly.

Textbook: (Required)

1. Horowitz, P., and Hill, W., "The Art of Electronics, 2e", Cambridge University Press, 1989. ISBN: 0-521-37095-7

Textbook: (Recommended, not required)

2. Hayes, T. C., and Horowitz, P. "Student Manual for the Art of Electronics", Cambridge University Press, 1989. ISBN: 0-521-37709-9

   In addition, technical data sheets and application notes will be available on CD-ROM, and students will be required to access technical information on the Internet. Each topic will be covered in detail in web-based lecture modules.

Equipment & Supplies:

The course is designed around a very small number of common components that will be supplied. To cover the cost of these we will have a lab fee ($100), but you get to keep the circuits you build. If you're pretty serious about building circuits in the future, we recommend that you also purchase your own test meter and hand tools (wire stripper, soldering iron, etc). These are not too expensive, ask the instructor.

Outline of Modules:

Module 01: Basic Analog Circuits, Components, and Intro to Integrated Circuits

- Ohm's Law and other useful stuff
- Passive components
- Discrete active components
- Linear (analog) integrated circuits, Overview
- Digital ICs, Overview
- Identification of electronic components
  - Packages (basics)
  - Pin numbering
  - Manufacturer ID
  - Identifying marks (resistors & capacitors)
- How to Draw a Schematic Diagram
- Internet resources: manufacturers datasheets, sample parts, application notes…

Module 02: Introduction to Building and Testing Circuits

- Tools: soldering, desoldering, solderless bread boards, wire types, etc.
- Standard Laboratory Bench Instrumentation
  - VOM
  - Oscilloscope
  - Power Supplies
  - Signal Generators
- Electrical Safety
- Basics of circuit assembly, layout, PCB design, ordering PCBs over the Internet

Module 03: Op Amps I: Introduction to Operational Amplifiers (Op-Amps)

- Most important & commonly used Op-Amp performance characteristics
- Ideal Op-Amp behavior
- Basic Op-Amp circuits & applications

Module 04: Op-Amps II

- Detailed discussion of Op-Amp performance characteristics
- Filters
- Comparators
- Buffers
- Op Amp Comparator (Schmidt Trigger) with Hysteresis
- Micro-power design
- Single-supply operation

Module 05: Op-Amps III

- Function generators: sine wave, ramp, square wave & pulse
- Output Power Amplifiers
- Norton Amplifier (Current Feedback)
- Instrumentation Amplifiers
- Noise Reduction, grounding techniques

Performance Enhancement
PCB Layout considerations for precision, low noise, high speed performance

Module 06: Power Supplies & Power Management
- linear
- switching
- batteries
- solar
- generators & alternators
- regulators & references
- grounding
- fuses (standard, slow-blow, resettable)

Module 07: Digital Circuits
- Combinatorial Logic
- Standard Logic Gates
- Logic families (operating characteristics)
- Standard digital function packages:
  - Logic gates
  - Oscillators and clocks
  - Shift registers
  - Digital Multiplexers (Mux – Demux)
- High speed logic
- Micro-power design considerations
- Internet-based resources: datasheets, sample parts, application notes

Module 08: Hybrid Circuits and Signal Conversion
- Digital to Analog Conversion (current and voltage modes)
- Analog to Digital Conversion
- Voltage to Frequency and Frequency to Voltage Converters
- Analog Multiplexers

Module 09: Microcontrollers I: Introduction to Embedded Systems
(Based upon the Microchip PIC16C/Fxx families)
- Basic Architecture of Microcontrollers
- Programming fundamentals
  - Introduction to assembly language
  - Introduction to PIC-C (an inexpensive and popular C compiler)
  - Introduction to MP-Lab
- Hardware considerations: how to implement a microprocessor or microcontroller

Module 10: Microcontrollers II: Embedded Systems Layout, Hardware & Peripherals
- Source code
- Fuses
- WDT

I/O considerations, pull-up & pull-down

Module 11: Microcontrollers III: Advanced Applications
Typical peripherals and functions
PWM
Interrupt
ADC
Clock/Timer Modules
Oscillator basics
Micropower operation, design considerations
Implementing feedback control
DSP

Module 12: Digital Memory:
Flip-Flops
Counters
Registers
RAM and ROM
SRAM, DRAM, NV-RAM
FIFO
PLD

Module 13: Sensors and Transducers
This module will be divided up into sections, and students can select from among the sections as they choose:
Electro-optical devices
Temperature, humidity, pH
Force and Pressure
Position and displacement (linear and angular potentiometers & encoders)
Velocity and Acceleration
Liquid Level
Hall effect sensors
Signal quality and noise reduction techniques

Module 14: Discrete components: advanced considerations and "real" behavior
Real (non-ideal) behavior of capacitors, resistors, diodes, transistors, switches (bounce), pots (drop out) etc…

Module 15: Assembly and Hardware Considerations (Human and Real World Interface)
PC boards, solderless breadboards, wire wrap
Standoffs & spacers
Enclosures
Power Entry
Cables

Connectors
Switches: types, nomenclature, functional characteristics (see LabVIEW)
Potentiometers: types, linear, log, audio taper, multi-turn, trimmer
Indicators
Basics of circuit assembly, layout, PCB design, ordering PCBs over the Internet

Module 16: Biological Interfaces

- Human interface considerations & safety
- Implantable devices
- Biopotential Electrodes
  - Conducting vs. non-conducting (Webster)
  - Surface
  - Nerve-cuff

Module 17: Electro-mechanical systems

- Solenoids
- Peltier devices
- Step motors and controllers
- DC motors: standard and brushless
- Motor controllers and drivers (use of the LMD18245 DC Motor Controller)
  - (option: use SGS Thompson p/n L298 H-bridge; Mauser)
- Open and closed loop control of motion, temperature, and force

Module 18: Machine Interface Design

- RS-232, RS-422
- Parallel Port
- USB
- IEEE 488

Module 19: Data Acquisition Systems (Introduction)

- Data Acquisition Systems:
  - LabVIEW
  - USB DAQ (module from B&B Electronics)
  - Home-built systems

Module 20: Wireless Communication

- Infra Red (IR) circuits
- Radio Frequency (RF) circuits

Module X1: Instructional Module Design

Based upon the observation that students often make excellent laboratory instructors, for this module the students will be required to develop a significant project for inclusion in future modules for this course. The students must propose a circuit concept to the instructor, develop content for the web-based tutorial, design, build, and characterize the relevant circuit(s). The resulting material will be considered for inclusion in future modules. For many students, this will be their first opportunity to develop instructional material, so it will provide an interesting and unique experience for the student, as well as providing new material for inclusion in the course.

Module X2: Instrumentation Research Project

Students may select from a pool of pre-defined projects, or they may propose a project themselves. Projects will include aspects Mechanical or Biomedical engineering, or may involve any other area with prior permission from the instructor, such as remote data logging systems for industrial or military applications, event detection and monitoring, transduction of thermal, fluid, or physiological signals for research purposes, etc. Students who are working on sponsored projects, such as the Solar Car Team, Human-Powered Helicopter, Baja Racing Team, etc., are encouraged to develop electronics projects for those activities if they wish to do so. Projects must be approved by the instructor. Each student or team will be required to generate a brief, 1-page proposal for approval before beginning their project.

Module X3: Reverse Engineering of Circuits

Students will select an existing, commercially available circuit from a source mutually agreeable to the students and instructor. The students will then “reverse engineer” the circuit: identify components, map PCB traces, decipher interface hardware functions, and so forth. The students will then splice all or a portion of the pre-existing circuit into another system for which the reverse-engineered circuit will perform some useful function. Examples include the splicing of a toy controller circuit into a robotics or game platform; a sensor may be connected to a computer I/O circuit, etc.

Module X4: Introduction to PSpice Models

Students will learn the basics of using PSpice models to model components based upon the manufacturers specifications, and will use web-based tools to evaluate test circuits, use test points to follow waveforms throughout a circuit, and optimize the performance of a circuit based upon an initial Design Specification. Students will be required to make extensive use of web-based resources, such as:

http://www.pspice.com
http:/www.orcad.com

The students will cover each topic in the module, take a quiz, and then go to the lab to build and test the required circuits. The instructor or a laboratory assistant will be present at defined times to provide direct assistance and advice during the lab work. Students can ask questions either by e-mail while reviewing the module materials, or in person at any of the laboratories, or during the instructor’s office hours. One advantage of this architecture is that each student can spend as much or as little time as necessary on each module, based on his or her prior experience.

This is intended to be a very flexible set of instruction modules, so each module will have a suggested sequence of prior modules to complete. In addition, suggested sequence templates will be provided. For example, a student doing research that required the development of a digital motion control system might take the following sequence of modules:

Module X: Introduction
Module X: Digital Circuits
Module X: Embedded Microcontrollers
Module X: Machine Interface Design
Module X: Electro-mechanical systems

A student interested in developing a remote sensor for outdoor field applications, such as a disdrometer (precipitation logger), might elect the following sequence:

Module X: Introduction
Module X: Analog Circuits and Linear Integrated Circuits
Module X: Digital Circuits
Module X: Hybrid Circuits and Signal Conversion
Module X: Microcontrollers I, II, III
Module X: Sensors and Transducers