Teaching Electronics and Instrumentation through an Innovative Core Design Laboratory in Sophomore Year

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Introduction

Stevens Institute of Technology has completed implementation of a revised Engineering Curriculum to include an expanded design course sequence, having a design course each semester to form a *Design Spine*[1]. The Design Spine allows development of many of the "soft skills" demanded of engineering graduates, as embodied in ABET Criteria 2000, by evolving them over the four years of the design sequence. It is also a means to enhance learning, as each of the design courses is linked to engineering courses taught concurrently. The first five design courses of the *Design Spine* are core requirements for all engineering disciplines. This takes the students into the second half of Junior Year when they take Design 6 in their chosen discipline. Design 7 & 8 are the disciplinary capstone senior design courses in Senior Year.

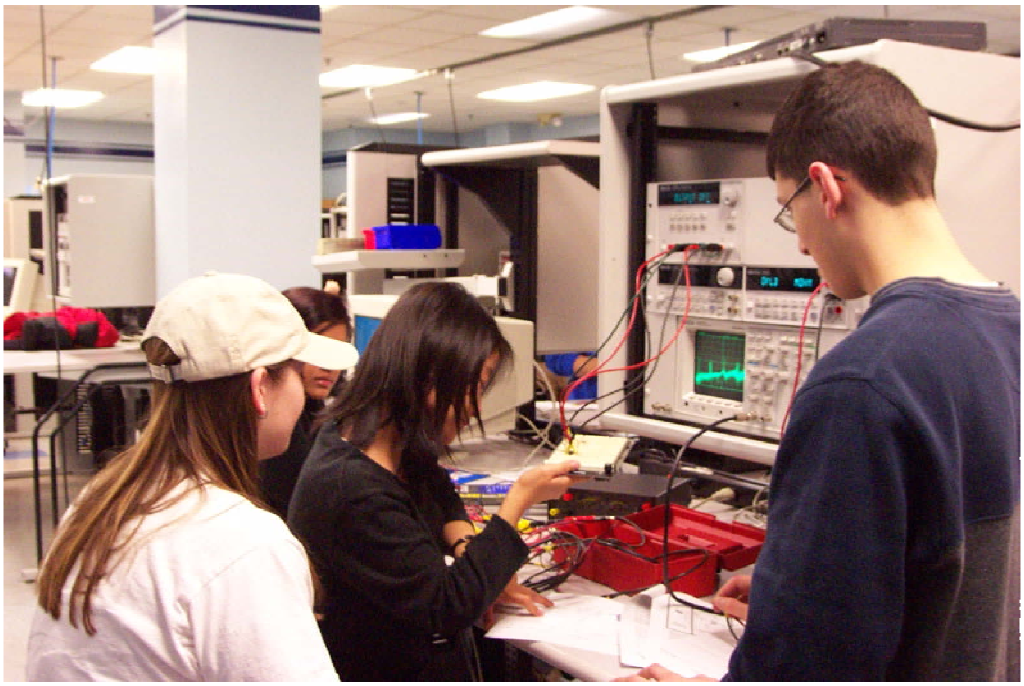
The core sequence starts in 1st semester with an introductory design experience with some linkage to a concurrent Graphics course[2]. Elements of teaming, project management, economics and effective communication are included. The second half of the course is focused on a major team project to build a robot that can negotiate obstacles and fulfill a prescribed task in competition with the robots from other teams. The project introduces students to sensors, algorithm development and microprocessor programming, and it is also fun! The design sequence continues in the 2nd semester of Freshman year with a design course that strongly links to a Mechanics of Solids lecture course[3]. The third design course links to the Thermodynamics and Energy Conversion course[4]. These design laboratories further advance the various threads in teaming, project management, communications and economics of design. The 3rd semester also includes an introductory Circuits course and laboratory. This is followed in the 4th semester by a lecture course in Electronics and Instrumentation coupled to a design laboratory, Engineering Design 4, which is the focus of this paper.

Engineering Design 4 – Electronics and Instrumentation

The Engineering Design 4 core laboratory is taken concurrently (co-requisite) with a 3-credit lecture course in this topic. The syllabus for the lecture course is one that builds on a traditional 3-credit Introduction to Circuits course (pre-requisite) taken in the 3rd semester. It consists of rectification, filtering, feedback concepts, operational amplifiers, transducer operation,

Proceedings of the 2003 American Society of Engineering Education Annual Conference and Exposition

instrumentation amplification, interfacing D/A and A/D and digital signal processing.
The design laboratory is housed in a state of the art facility, the Hattrick Laboratory, which was brought online in Spring 2000, thanks to funding from a generous alumnus. Classes meet for three hours a week. Section size is typically limited to 27 students, to provide for three-person groups each using as separate instrumentation station comprising a suite of Hewlett-Packard equipment, signal generator, power supply, multimeter, oscilloscope. A p.c.-based data-acquisition system using a National Instruments interface is also connected running LabView and MatLab software.



Rationale

Two factors influenced the inclusion of an electronics and instrumentation design course in the core requirements during the development of the present Stevens engineering curriculum. The first was continuation of the Stevens traditional of an extensive core that provides a broad-based engineering education, rather than one that is narrowly focused within a discipline, yet one embedded in a curriculum that also provides sufficient depth in the disciplines to meet professional and accreditation requirements. Second was the recognition of the impact of software tools in providing a common flexible approach to the collection and analysis of sensor and other signal data across a variety of engineering disciplines and the associated computer-based data acquisition and control systems, replacing custom instrumentation. It was thus considered that all our engineering students would benefit from a foundation level of understanding and facility with the operation and use of sensor systems and their interfacing with computer-based data acquisition and control systems. By placing this material within the context of a design course, it allows students to do more than run experiments; it requires them to apply what they have learned, both in lecture and laboratory, to applications that emulate engineering practice.

Syllabus

The syllabus of Engineering Design 4 includes an initial two weeks for tutorial sessions in each of the two major software tools to be used, namely MatLab and LabView. Simulink is introduced later in the course and is a key part of the design project. As the curriculum implementation has matured, students increasingly have been exposed to and used these tools in previous courses, such as in mathematics (MatLab) and the first Circuits laboratory (LabView). We anticipate that within the next couple of years the in-lab tutorials will be replaced by pre-lab refresher resources as students have both software packages on their required laptops provided, under the Stevens Personal Computer Program will replace the tutorial sessions.

In the Circuits lab of Semester 3, the students have an initial exposure to operational amplifiers and use discrete instruments in the instrumentation stations of the Hattrick lab to evaluate the op. amp. characteristics. In the third week of Design 4 they apply this knowledge by building a differential amplifier circuit to connect to a temperature sensor and evaluate its performance. A pre-lab operational amplifier review is available online. For this activity Stevens has designed and fabricated a custom circuit board to which up to four op. amps can be attached and provides flexibility for component attachment, jumper and instrument lead attachment and also interfacing cable connection. It provides a more intuitive arrangement than the standard Proto-Board approach and more successful circuits. The students still have experience with the Proto-Board approach during the Circuits lab. Initial work on the amplifier circuits uses the discrete electronic instruments and power supplies of the instrumentation stations.

The next two weeks are devoted to understanding the operation and characteristics of a number of sensors. As such it continues a sensor thread through the Design Spine. In Design 1 students used commercial sensors, such as photodiodes, connected to a microprocessor for their robots. This was followed in Design 2 by use of strain gages. While students learned how to apply the strain gages to measure deflection of a beam, the output went to a "black box" for signal amplification and display. In Design 3 students used pressure and temperature sensors. They revisit these in Design 4, but now "open the black box" so to speak!

The next phase, in Weeks 6&7, is learning to interface sensor circuits and the use of virtual instruments through LabView for data collection, signal processing and control. Matlab is used for the data analysis.

Weeks 8 thru 14 are devoted to a major team design project that allows students to be creative as well as encouraging an entrepreneurial approach. The project requires teams to design a product that incorporates sensors, interfacing, data collection analysis and its use in control. The project also provides a vehicle for continuation of a number of important Design Spine threads that address entrepreneurship, project management, economic analysis, market analysis and effective technical communications.

As part of the introduction to the design project, groups are given a tutorial on the use of Simulink to model dynamic systems. They all work on developing a Simulink model of an electroplating tank system. It is a tank-filling problem with inlet valve and drain and uses on-off control. They also get a short primer at this point on PID control. This application also points to our desire to expose all engineering students as they move through the Core to applications in a broad range of engineering disciplines. In this case one that they view as a chemical engineering application. In Design 2 all students had to design in the context of Civil/Mechanical engineering applications for trusses and beams for a gantry crane project.

The context of the design project is one in which students are encouraged to be creative, entrepreneurial and follow their interests. They are expected to come up with a product concept that incorporates the elements that have been addressed in the course, namely sensors, interfacing, control etc. while building in real world constraints. The team has to provide a Simulink model of the device that they design as part of the deliverables. They are also required to assess the market for their device, the economics of its design and related issues. A synopsis of the instructions to the students is included below:

Design Project Details

Overview

Each Project Team will design a system that includes use of analog sensors coupled to data acquisition instrumentation in an application to be chosen by the Team in consultation with the Instructor and the TA. The context will be one of a commercial product development Team in which the TA acts as the immediate supervisor and the course Instructor is the senior manager.

Requirements

The Project must include the following:

- *Be approached as a business opportunity and the Team functions as such.*
- *Use the software tools covered in the course along with a SimuLink model of the proposed system.*
- *Incorporate analog sensors coupled to a data acquisition system and feedback to control some aspect of the Project.*
- *Include an analysis of the market opportunity, liability considerations and cost economics.*
- *A formal Proposal must be made to the Instructor/TA prior to the approval of the Team's Design Project.*

Teaching mode

A key feature of the course is that adjunct professors, who are practicing engineering professionals, teach the laboratory sections supported by teaching assistants. These professionals have played a major role in the course development. While they come from various disciplines, they have all had extensive of using electronics and instrumentation and can bring a "real world' perspective to the course. The students respond well to this.

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Biographical Information

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