Value Added Engineering Education

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Abstract

A significant problem that has surfaced over the years in many engineering programs is the loss of laboratory experiences in favor of more theoretic intensity in upper division courses. In electrical engineering (EE) curricula, the majority of programs now include laboratory work only in circuits, electronics and logic design. Courses such as control theory, electromagnetics, communications, and others have lost their labs due to the increasing tightness of the curriculum and the movement from the practical towards the theoretic. Many faculty over the years have lamented the loss of the "hands on" experience of lab work, but little if nothing has been done, short of software simulations, to rectify the problem. This paper discusses an approach to providing a laboratory experience to students in upper-division courses that we have titled Value Added Engineering Education, or VAEE, that builds on lower-level laboratory experience using a data acquisition system and a specializd prototyping fixture to afford students in advanced courses a laboratory activity.

Introduction

Engineering education has ergone a significant number of changes over the years, as it should. One significant event in American engineering education was the paradigmatic shift to engineering science from engineering practice that occurred in the 70's [1]. This was largely due to the cold war and the space race that ensued following the 1957 launch of Sputnik and the ensuing paranoia that it caused.

The Sputnik launch changed everything. As a technical achievement, Sputnik caught the world's attention and the American public off-guard. Its size was more impressive than Vanguard's intended 3.5-pound payload. In addition, the public feared that the Soviets' ability to launch satellites also translated into the capability to launch ballistic missiles that could carry nuclear weapons from Europe to the U.S. [2]

Prior to this change, engineering curricula were significantly *core focused*, where each engineering student took an extensive selection of courses common to multiple engineering disciplines. Under this system, specialization did not occur until late in the program. Modern engineering curricula have become highly specialized and commonality between disciplines typically occurs only in the mathematics and sciences and occasionally in an introductory course.
Aside from the changes occurring to course content, many organizations found their curriculum shrinking [3] due to increased demands on student time caused by specialization while the fundamental length of time (four years) and liberal arts core remained unchanged. For years engineering faculty have anecdotally commented on the difficulty of achieving an engineering education in four years. Some schools have developed specialized curricula, often combining other disciplines into the program or graduate work, to achieve this goal.

In general, as the curricula changed to meet the new demand for greater science emphasis, the main variable of change was the theoretic aspects of coursework. Since engineering education was moving away from the practical and more towards the theoretic, while the curricular content was becoming more specialized, the amount of laboratory experience decreased. This process had an added benefit in costs and time at the expense of the experience. Since we are an electrical engineering department, our focus has been on the EE curriculum, but the methods we are using to expand the laboratory experience are applicable to other disciplines as well.

An Integrated Laboratory Experience Across The Curriculum

One problem that seems to cycle through engineering and at various rates through the individual engineering disciplines is that of retention and recruitment. A significant problem for engineering recruitment lies with the fact that many prospects, those students completing their secondary educations (High School in the U.S.), are unaware of what engineering is and how it is pursued, so a good deal of effort is expended to career counsel the prospects[4]. A different problem occurs with retention in that much of an engineering curriculum must follow a strict foundation of mathematics and physics, leaving many students to wonder when the engineering will start. In 2000 engineering education researchers from industry, secondy and higher education devised a novel program to enhance both recruitment and retention [5] called *The Infinity Project*. Initially designed for recruitement purposes, the program was implemented in Texas high schools to entice potential students into following engineering careers. What the developers from higher education discovered was that the program was also useful for retention purposes when offered in condensed form as a freshman introductory course.

Lamar University Electrical Enginering (LUEE) was awarded a grant in 2002 to implement a version of the Infinity Project as our ELEN1200 *Introduction to Electrical Engineering* course. Our implementation, like the others, was an immediate success. One of the reasons that we attribute to the success of the program is the hands-on nature of the material presented. The course is conducted in the laboratory and the main component of it is a set of *digital signal processing* (DSP) experiments that are performed with very sophisticated hardware development boards and a specialized icon-driven software that makes development of complex systems almost trivial. Although the students are not exposed to the underlying theory, they are given an excellent hand-on introduction to the basic concepts.

In 2003, Texas universities were offered free laboratory hardware from National Instruments Corporation in the form of the Electronic Laboratory Virtual Instrumentation Suite, or ELVIS (see Figure 1). LUEE took advantage of this offer and received ten of the units. What the ELVIS system does is allow the user to access a suite of virtual instruments (meters, signal generators, oscilloscopes, etc.) developed under the LabVIEW programming environment from a prototyping board [6]. The prototyping board allows access to various signals linked to a Data Acquisition (DAC) card hosted by a desktop computer. At the time we acquired the ELVIS systems, LUEE was running classical circuits and electronics laboratories using benchtop equipment, some of which was quite old given the limited resources at our disposal. We quickly updated the experiments in those courses to take advantage of the ELVIS capabilities and in the process realized that the ELVIS concept gave us an outstanding level of flexibility in addition to advanced capabilities.

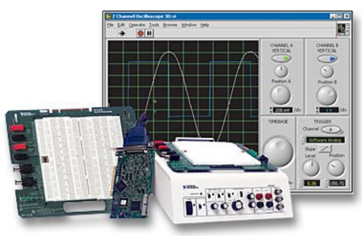


Figure 1
National Instruments
ELVIS System

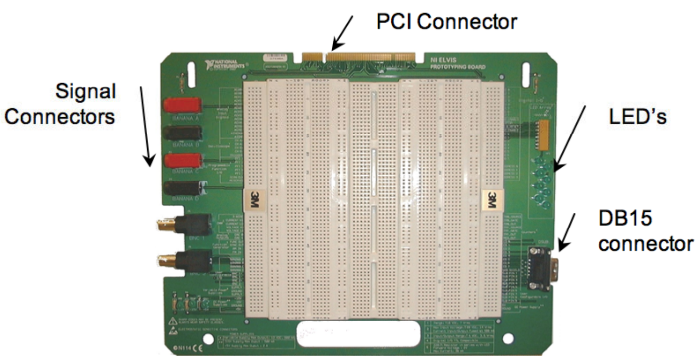
One of the basic concepts germain to the ELVIS system is the removable prototyping board shown twice in Figure 1. One is standing on edge at the far left and the other is mounted to the top of the console unit (box in center with control panel). The student is expected to purchase this board and then use it for lab work involving the ELVIS; in fact, the board is fitted with holes so that it can be inserted into a 3-ring binder for easy transport and storage. Unfortunately, the board is too expensive for most students and many programs simply purchase a board for each ELVIS console unit and leave them installed. Student lab groups then share them.

In our initial implementation of the ELVIS system in our circuits and electronics laboratories, we also used the original prototyping board and hadstudent groups of no more than three share them. The use of the ELVIS system and the LabVIEW programming environment brought a new level of capability to our laboratories. In the past, the department had suffered from increasingly aging equipment and reduced budgets for new instrumentation. At the same time, the use of LabVIEW was more consistent with existing engineering practice where data acquisition systems and computer-controlled instrumentation are the norm rather than the exception.

ELVIS and the Introductory Lab Experience

After offering our ELEN1200 Introduction to Electrical Engineering freshman course for two years using the Infinity Project guidelines, a decsion was made to enhance the course by removing four of the sixteen DSP-oriented lab assignments (it should be noted that all of the Infinity Project labs are DSP-based) and replace them with what we call the *electrical engineering paradigmatic labs*. We defined four fundamental paradigms: circuits, electronics, electromagnetics and logic circuits and developed freshman level lab experiments that address the paradigms. At the writing of this paper, we are developing a fifth lab to address the *control systems* paradigm. In these labs, the student gets early exposure to an RLC network (circuits), an op amp (electronics), a nand gate (logic circuit) and a transformer (electromagnetic). In order to implement these labs, we utilized our ELVIS systems, which allow the labs to be, to borrow a phrase, be "plug-and-play", which is a requirement at the freshman level.

At this stage in the development of our courseware, we concluded that it would be useful for our students to own their own prototyping boards for the ELVIS system since we were now using the ELVIS in three courses. This was consistent with the original intent of the ELVIS, but the faculty felt that the cost of the board did not justify requiring the students to purchase them. The faculty also observed that much of the ELVIS prototyping board was underutilized. Figure 2 shows details of the ELVIS prototyping board. At the top of the board there is a PCI connector that plugs into a socket mounted on the top of the ELVIS station (or console). This connector allows signals from the power supplies and computer to be available at the breadboarding blocks (white rectangular area at board center) and allows signals to flow out from the board to the data acquisition system. On the left side are ancillary signal connectors, banana plugs and BNC. On the right side of the board are a set of eight LED's and a DB-15 connector. None of our labs use any of these ancillary connectors or the LED's. Additionally, much of the large breadboarding area is not needed for the labs that our students conduct. On the bottom are the three-ring binder holes, the large rounded rectangular hole serves as the center binder hole, a carrying handle and as an attachment point for a clamping tab when the board is installed in the console.



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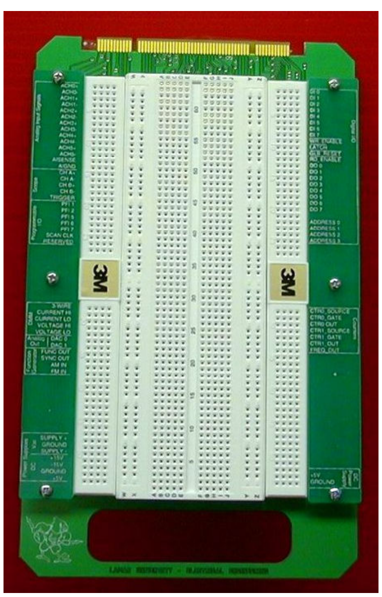

Figure 3. LUEE-ELVIS board

Given the reasons above, we set out to design our own board, a smaller and simpler version of the standard ELVIS device, but more importantly, less expensive. This led us to the design shown in Figure 3, what we call the LUEE-ELVIS board. This board costs less than half that of the standard board and is more easily carried and stored.

The LUEE-ELVIS board is roughly one-third the size of the standard board it replaces. We found the breadboard area to be more than adequate for all of the labs (introductory, circuits and electronics) that our students conduct using it. The LUEE-ELVIS board has a design enhancement in that a pair of panels is added on each side of the prototyping area that are raised on hardware risers to the level of the breadboard. These panels are printed with the signal names and are directly adjacent to the signal take-off points on the breadboard. This eliminates the parallax problems inherent with the original board. A graphic of the school mascot is printed on the lower-left corner of the board that gives the students a greater sense of community and team-participation.

Value Added Engineering Education

Following the implementation of the LUEE-ELVIS board, it became clear that all LUEE students, starting at the freshman level, would possess boards and would use those boards over three semesters of coursework spanning three years of our curriculum. This knowledge, and the desire to give the students maximum use of their equipment, spawned the idea of giving students homework assignments in advanced courses that they would conduct in the lab using their LUEE-ELVIS boards. This would allow courses that either never had a lab experience or lost the lab experience to increasing amounts of material to be covered under restricted lecture time to engender a *value added* lab experience. Hence the phrase, *Value Added Engineering Education*.

As an example of the VAEE process, Figure 4 shows VAEE system identification modules intended for use in our ELEN4351 Control Engineering course. The modules contain a simple 1st-order RC circuit with parameter values unknown to the students. Each student receives a different circuit and is instructed to go to the lab, and use LabView and the ELVIS system to stimulate the module with an impulse and step function to determine the transfer fuction of the system in the module. This requires skill learned in circuit theory lab; however, looking at the module as a system rather than a circuit underscores control systems theory. The student then returns the module along with a brief analysis and the work is graded as a homework assignment.

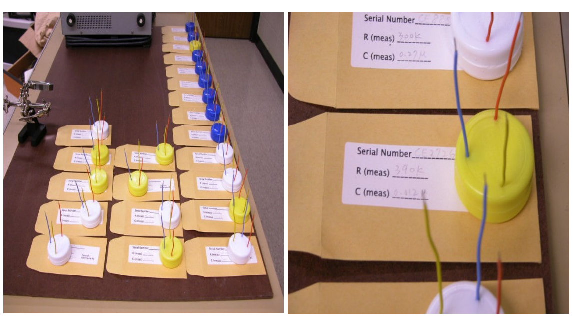

Figure 4. Systems identification

Discussion and Summary

We have discussed an approach to the augmentation of theory-only courses with the addition of a laboratory experience that is treated as a homework assignment that we call *Value Added Engineering Education*. This is made possible through a sequence of preperatory laboratory work with specialized hardware and software. Certainly this sort of program could be implemented with standard equipment, however, the fluid and sequential nature of the program lends an element of simplicity that supports usage and minimizes difficulties. This program has been under development and the first actual implementation of VAEE assignments will not occur until the fall of 2006.

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